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Distribution and Abundance of Submerged Aquatic Vegetation in the Lower Chesapeake Bay, Virginia

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J. Robert Orth, Kenneth Moore, Hayden Gordon

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The distribution and abundance of Submerged Aquatic Vegetation (SAV) in the lower Chesapeake Bay was delineated with aerial photography and surface information. All SAV were mapped from aerial imagery onto topographic quads (1:24000) with a zoom transfer scope. The SAV beds were classified into 4 density categories based on comparison with a crown density scale.

A comparison with earlier surveys indicates that the distribution of the SAV species found in the saline portions of the Bay have shifted from upriver and upBay sites to the mouths of rivers and lower Bay sites.

SAV beds in six selected areas of the lower Bay were examined for historical changes in the distribution and abundance of SAV. Aerial photographs examined show sparse coverage of grass in most areas in 1937 with dense coverage in the 1950's and 1960's continuing through 1971. Significant declines were noted in the period of 1971 through 1978.

The distribution of SAV species in Virginia's tidal waters was classified into three groupings: (1) (Zostera and Ruppia) dominates the saline portions (2) (Potamogeton, Zannichelia) Ologohaline regions (3) (Ceratophylum, Majas) fresh water.

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DISTRIBUTION AND ABUNDANCE OF SUBMERGED AQUATIC VEGETATION IN THE LOWER CHESAPEAKE BAY, VIRGINIA

by

Robert J. Orth
Kenneth A. Moore
and
Hayden H. Gordon
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

Contract No. EPA R805951010

Project Officer

William A. Cook
Chesapeake Bay Program
U.S. Environmental Protection Agency
Region III
6th and Walnut Streets
Philadelphia, Pennsylvania 19106

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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FORWARD

The submerged aquatic vegetation (SAV) of the Chesapeake Bay fill an important ecological role in the Bay system. Aquatic grasses function as food, shelter, and habitat and breeding areas for finfish and shellfish, waterfowl, and species of the lower trophic levels.

In recent years, a noticeable decline in the distribution and abundance of the SAV has been observed. The EPA Chesapeake Bay Program, in attempt to understand the role of the grasses, has developed an SAV research program which will examine the cause-and-effect relationships potentially responsible for the decline in bottom grasses. Research results will provide data for a management plan aimed at protecting and enhancing the growth and propagation of the Bay's submerged plants.

One of the tasks of the SAV program is the conduct of studies to delineate the distribution and abundance of the grasses in the Bay system. This report presents the results of that work in the Virginia waters of the Chesapeake Bay. Compatible studies are being conducted in the Maryland waters, and the results will soon be available.

This effort, in combination with the Maryland Study, establishes the first comprehensive inventory of the SAV in the entire Bay system. The products of the study, a series of maps (1:24,000 scale), will serve as a baseline to measure future changes in the abundance of the Bay grasses.

Follow-up studies are being conducted in 1979 and are projected for 1980. It is intended that the products of this research will not only be useful to Bay managers in making decisions concerning Bay resources and uses but also will assist in defining a cost-effective program for future monitoring of Bay grass populations.

ABSTRACT

The distribution and abundance of submerged aquatic vegetation (SAV) in the lower Chesapeake Bay and its tributaries were delineated with color aerial photography and surface information. Over 8500 hectares of SAV were identified on 31 topographic quadrangles. To enable computer retrieval of the aerial resource information, all information from the 1978 mapping effort was entered into a data base based on the Universal Transverse Mercator coordinate system.

The greatest concentrations of SAV were found at the mouths of the largest tidal rivers and creeks along the Chesapeake Bay shoreline, and to the east of Tangier and Great Fox Islands. Freshwater and low salinity portions of Virginia's tidal rivers were generally found lacking in large areas of SAV, although numerous small fringing beds and pocket areas associated with adjacent tidal marshes were identified.

Based on the co-occurrence of the 20 species found at 93 locations throughout Virginia's tidal waters three species associations of SAV were identified. Zostera marina and Ruppia maritima dominated the higher salinity regions, Zannichellia palustris and others the lower salinities regions and Ceratophyllum demersum and others in the freshwater regions. Of the total of 20 species of SAV that were identified, 18 of the species occur primarily within the tidal rivers. Species richness was inversely related to salinity with the low salinity areas having the greatest number of species.

Seventeen transects conducted across large SAV beds in six areas around the Chesapeake Bay shoreline revealed Ruppia to be dominating the shallow, more protected areas (+1 to -4 dm) with Zostera and Ruppia co-occurring at intermediate depths (-4 to -8 dm) and Zostera predominating at deeper depths (-8 to -12 dm). Bottom types varied from silts to coarse sands with variations in sediment not directly related to speciation of these two species.

Analysis of the historical distribution of SAV throughout the lower Bay was accomplished by use of aerial photography for six selected areas. Low levels of SAV in 1937 increased significantly until approximately 1971 when a precipitous decline in coverage occurred during the period of 1973-1974. This decline continued until 1978 when the lowest levels in SAV over the last 40 years were recorded.

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LIST OF ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS

Submerged Aquatic Species

Cy -- Callitriche verna
Cd -- Ceratophyllum demersum
C -- Chara sp.
Ec -- Elodea canadensis
En -- Elodea nuttallii
Ms -- Myriophyllum spicatum
Nf -- Najas flexilis
Ng -- Najas guadalupensis
Nm -- Najas minor
N -- Nitella sp.
Ps -- Potamogeton crispis
Pi -- Potamogeton filiformis
Po -- Potamogeton foliosus
Pn -- Potamogeton nodusus
Pc -- Potamogeton pectinatus
Pr -- Potamogeton perfoliatus
Rm -- Ruppia maritima
Va -- Vallisneria americana
Zp -- Zannichellia palustris
Zm -- Zostera marina

Emergent and Other Species

B -- Bidens sp.
Bh -- Baccharis halimifolia
Jr -- Juncus roemerianus
L -- Lemna sp.
Nl -- Nuphar luteum
Pd -- Pontederia cordata
Pv -- Peltandra virginica
Sa -- Spartina alterniflora
Sc -- Spartina cynosuroides
Sp -- Spartina patens
Ta -- Typha angustifolia
Za -- Zizania aquatica

DEFINITIONS

Dominant -- The most abundant species characterizing the mapping unit.

Abundant -- Species found in quantity essentially throughout the mapping unit.

Frequent -- Scattered species or individuals occurring regularly throughout the mapping unit.

Occasional -- Individuals or colonies occurring infrequently. These may or may not be unusual.

Rare -- Individual occurring very infrequently. These may be considered unusual.

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EXECUTIVE SUMMARY

The distribution and abundance of submerged aquatic vegetation (SAV) in the lower Chesapeake Bay and its tributaries were delineated with color aerial photography and surface information. Methods used in this study were reviewed and modified when necessary in response to comments from EPA's Chesapeake Bay Program, Quality Assurance Coordinator. SAV were mapped from aerial imagery onto topographic quadrangles (1:24,000) with a zoom transfer scope and areas of SAV beds computed with an electronic planimeter. All SAV beds were classified into four density categories based on a comparison with a crown density scale: <10% cover, 10-40% cover, 40-70% cover and 70-100% cover. Significant beds of SAV were identified on 31 quadrangles with 27 occurring in the mesohaline and polyhaline areas where *Zostera marina* and *Ruppia maritima* were found to cover over 8400 hectares (20,750 acres) of shallow bottom. The remaining four quadrangles depicted oligohaline and freshwater areas which were vegetated by a variety of species including: *Zannichellia palustris*, *Ceratophyllum demersum*, *Vallisneria americana*, as well as several species of *Potamogeton* and *Najas*. These totaled 137 hectares (340 acres).

Virginia's tidal rivers, which are largely oligohaline and freshwater, were generally found lacking in large areas of SAV, although numerous small fringing beds and pocket areas associated with adjacent tidal marshes were identified through field investigations. Several areas, including a region of the Potomac River in the vicinity of Dahlgren, and the Chickahominy River, a tributary of the James, contained large enough beds of SAV to be mapped. However, the greatest concentrations of SAV were found at the mouths of the largest rivers and creeks and along the Chesapeake Bay shoreline where mesohaline and polyhaline conditions predominate. The most significant areas of these were: 1. along the western shore of the Bay between Back River and the York River; 2. around the shoreline of Mobjack Bay; 3. throughout the shoal areas east of Tangier and Great Fox Island; 4. behind large protective sand bars near Hungar's Creek and Cherrystone Creek which are located along the Bay's eastern shoreline.

The distribution of SAV species in Virginia's tidal waters were classified into three associations based on their co-occurrence; one association consisting of eelgrass, *Zostera marina* and widgeon grass, *Ruppia maritima*, which dominated the mesohaline and polyhaline portions of the Bay; a second association found in the oligohaline regions including the pondweeds *Potamogeton* spp. and *Zannichellia palustris*; and a third association primarily restricted to freshwater including coontail *Ceratophyllum demersum*. Although *Ruppia* is much more tolerant of freshwater than *Zostera*, it was not found to any significant extent in Virginia's rivers upstream from those areas where it co-occurs with *Zostera*. Species diversity (numbers of species) increased in an upstream direction with the third group, those restricted to freshwater, having the greatest species richness. Myriophyllum spicatum, water milfoil, occurred only in isolated areas and formed few significant beds, even in those areas where it previously had been very abundant in the 1960's.

Aerial overflights were made during the summer and winter of 1978. Comparisons of imagery obtained during these periods reflected, for the most part, the natural, late summer die-back of Zostera and Ruppia. Reductions in coverage on the imagery of between 40 to 83 percent were recorded. The densest areas of vegetation on the summer imagery were those most evident on the winter imagery. In addition, those areas which were observed to have the sparsest coverage (i.e. <40%) during the summer were not able to be observed during the winter flights. This does not mean that in these sparse areas there was no vegetation in the winter, but they were reduced to levels too low to provide an image on the aerial photography at the altitude flown.

The distribution of SAV (Ruppia and Zostera) in the last 40 years was delineated by changes in grass bed coverage in six selected areas. Mumfort Island and Jenkins Neck in the York, the East River in the Mobjack Bay, Parrott Island in the Rappahannock River, Fleets Bay and Vaucluse Shores at the mouth of Hungar's Creek on the Bayside of the Eastern Shore all showed a very reduced coverage in the late 1930's. This coincided with a period when Zostera had also declined along the entire East Coast of the U.S. The period between 1937 and 1953 showed a dramatic increase in areal coverage at all sites as well as increase in bed densities. The increase continued through the 1960's and in some areas until 1971 or 1972. Slight decreases were occasionally observed during this period at Mumfort Island, Jenkins Neck and Parrott Island. The largest loss of SAV occurred between 1971 and 1974, but especially in 1973. Both areal coverage and the density of the beds in all these areas, except the Eastern Shore site, showed a significant decrease. This decrease continued through 1978 when the distribution and abundance of SAV in each area was the smallest observed over the last 40 years.

In reviewing the past and present data, the distribution and abundance of SAV in the six selected areas in 1973 appeared very similar to the data collected for 1937-1938. This suggests that whatever factor or factors caused the major decline of the grass beds in the 1930's may also have been operating in the 1970's.

The dynamic nature found in certain grass beds was illustrated in the aerial photography by the dramatic changes in the distribution of the SAV at the Vaucluse Shores site. The grass bed alterations in this area were apparently due to the dynamics of the sandbars and sandpits found in this region. Both features had migrated and altered the contour of the shallows. Accompanying the changes in bar and spit formation were changes in grass bed distribution. As the bars and spits moved, certain habitats became unsuitable for SAV survival while other areas became more suitable with net migration of SAV into them. Evidence for this was confirmed by cores taken in the sand bar region adjacent to grass beds. Samples taken to depths of 1 meter contained remnants of eelgrass rhizomes at the core bottoms. These rhizome fragments were found closer to the surface as the existing grass bed was approached. In the northern section of the bed the area appeared to be shoaling. The habitat therefore had become more suitable for Ruppia than Zostera. General observations of sections of this northern part made between 1976 and 1978, indicated changes in species composition from Zostera to Ruppia. In addition, sediment cores taken in these predominantly Ruppia areas indicate dense Zostera rhizomes in close proximity to the sediment surface, confirming that Zostera was recently present. Thus, it appears that geological processes such as sediment transport are very important determinants in SAV distribution here.

Surface information was collected by field checking numerous sites along the lower Bay for species composition. More complete species composition distribution and percent cover data were analyzed in six vegetated areas (Mobjack Bay-Browns Bay, Ware Neck, and the mouth of the East River; Chesapeake Bay-Plum Tree Island and Horn Harbor; Bayside, Eastern Shore-Vaucluse Shores) of the lower Bay using a transect method. Seventeen transects conducted across these six areas revealed a co-dominance by two species, Zostera marina and Ruppia maritima. In general, Ruppia was found dominant in the shallow, more protected areas (+1 to -4 dm relative to MLW) with Zostera and Ruppia co-occurring at intermediate depths (-4 to -8 dm) and Zostera predominantly at deeper depths (-8 to -12 dm).

Bottom types found at the 17 transects varied from silts to coarse sands with the fine sand being the most common designation. Another bottom type not observed in the transects but found in a few SAV beds around the lower Bay was of relic oyster bars covered with a fine layer of silty-sand. Variations in bottom types did not appear to be directly related to speciation within the beds as both species were associated with each of the sediment types.

SECTION 1

INTRODUCTION

The shallow coastal regions of estuaries, bays, and rivers represent extremely important areas in coastal zone productivity. Their importance lies in the fact that these shallow zones are normally colonized by vast expanses of wetlands and submerged aquatic vegetation (SAV).

SAV systems serve multiple, functional roles in coastal ecosystems (Wood, et al., 1969; Thayer, et al., 1975; Stevenson and Confer, 1978). They superimpose a structural component on an otherwise bare sand or mud bottom. This structure serves as a habitat for many small sessile and slow moving invertebrate species such that the density and diversity of invertebrate species found in the sediments surrounding the leaves are significantly higher than adjacent, unvegetated areas (Marsh, 1973, 1976; Orth, 1977). There is also a much higher density of the more motile, macroinvertebrate species such as shrimp and crabs in vegetated areas compared with unvegetated areas (Heck and Orth, in press). In addition to the habitat function, SAV areas function as refuges for these same motile species by providing a source of protection from predators. The effectiveness of this refuge is apparently directly related to the density of vegetation (Heck and Orth, in press). The blades of SAV support a diverse and sometimes very dense epiphytic growth which is a source of food for herbivores and thus contributes to the overall high productivity of the system.

The combined primary productivity of the plant and associated algal components rivals that of many of the world's cultivated crops (Thayer, et al., 1975). There are also complex nutrient interactions occurring. For example, the individual plants have been shown to act as a "nutrient pump" moving nutrients from the sediment to the water column and vice versa (McRoy and Barsdate, 1970; McRoy and McMillan, 1977) with additional uptake of released nutrients by the attached epiphytes (McRoy and Goering, 1974). The leaves and roots of SAV are also capable of binding sediments and baffling currents, thereby stabilizing the bottom and preventing erosion and loss of sediment. Finally this overall importance of SAV does not end with the living plant. Detritus derived from SAV serves as a contributor to the detritus food chain, an attribute very important to the coastal areas.

Within the Chesapeake Bay, there are extensive shoal areas that are heavily vegetated with submerged aquatic vegetation. The Bay with its salinity regime spanning a range of 0 to 25^{o}/oo is represented by a variety of different SAV community types (Stevenson and Confer, 1978). The polyhaline and mesohaline areas are dominated by eelgrass, Zostera marina and widgeon grass, Ruppia maritima, while in the oligohaline and fresh water regions, there are approximately 20 species of SAV which include redhead grass, *Potamogenton perfoliatus*; sago pondweed, *Potamogenton pectinatus*; wild celery, *Vallisneria americania*; horned pondweed, *Zannichellia palustris*. Historically, emphasis on Chesapeake Bay SAV has been directed to its importance as a food for waterfowl. However, with the decline of SAV throughout the Bay in the early 1970's (Stevenson and Confer, 1978), the importance of SAV for primary production, nutrient cycling, prey refuge, contribution to food webs and sediment dynamics is now becoming apparent. It may be that the SAV systems constitute one of the most scientifically as well as aesthetically interesting areas in the Bay.

Because of man's ever increasing use and abuse of the coastal zone, it is becoming apparent that those systems which are important to the ecological well-being of the Bay must be properly managed. Management of the SAV resource must not only recognize the importance of the resource as outlined above but also where the resource is located and its abundance, as well as the dynamics of the system in both space and time. Thus the overall objective of this study was to delineate the distribution of SAV communities and to assist in understanding the dynamics of these systems from an historical perspective.

The accurate delineation of communities of submerged aquatic vegetation for the purpose of mapping their distribution and abundance can be exceedingly difficult, if not impossible. These communities are not static but represent dynamic elements whose distribution and abundance can vary both in space and time. Distinct differences in SAV beds can be observed in time frames of less than six months. Remote sensing techniques offer distinct advantages for this type of analysis of SAV communities. The main advantage of aerial photography is its presentation of a synoptic view of an entire bed and the adjacent areas. Aerial photography offers a permanent record of the grass area which can aid in depicting historical changes in grass bed formation. This could also aid in identification of grass bed alterations due to land use changes. Aerial photography is a relatively inexpensive method of inventory as compared to intensive field survey work, and the final product can provide an accurate map of the entire distribution of SAV in an area. Grass bed anomalies are observable on aerial photographs, e.g. sand bar and sand spit formations, halos (Orth and Gordon, 1975; Davis and Brinson, 1976; Orth, 1979) which may not otherwise be visible from the water surface. This synoptic overview allows the researcher to minimize his time in the field spent searching for anomalous areas, etc. by pinpointing areas of interest on the photography.

Aerial photography has been used successfully around the world for mapping many different SAV community types and examining associated environmental problems (Edwards and Brown, 1960; Lukens, 1968; Kelly, 1969a, b; Kelly and Conrod, 1969; Wile, 1973; Harwood, et al., 1974; Orth and Gordon, 1975; Pooni, et al., 1975; Davis and Brinson, 1976; Orth 1976; Steffensen and McGregor, 1976; Good, et al., 1978). These efforts which have been conducted under a variety of environmental conditions suggests that remote sensing techniques are the most efficient and cost effective methods for understanding the dynamics of SAV.

OBJECTIVES

The primary objectives of this study are as follows:

1. To accurately map the distribution of eelgrass, Zostera marina (and widgeon grass, Ruppia maritima where it co-occurs with Zostera) in the saline portions of the lower Chesapeake Bay using remote sensing techniques and appropriate surface information.
2. To map the distribution and abundance of SAV in selected areas of the fresh and oligohaline waters of the lower Chesapeake Bay's tributaries.
3. To delineate the different SAV species and their distributional patterns in the lower Chesapeake Bay and its tributaries.
4. To determine the extent of SAV recovery or losses from selected mesohaline areas based on historical SAV data (e.g. historical aerial photographs and previous vegetation surveys).

SECTION 2

CONCLUSIONS

The mapping of SAV beds in Virginia was accomplished using a Fairchild CA-8 cartographic camera with a 152 mm (6½ inch) focal length lens. The camera was mounted in the belly of a single-engine, fixed high wing DeHavilland Beaver aircraft and flown at altitudes of 2740 m to 3660 m. Film type of Kodak 24 cm (9½ inch) square positive transparency Aerochrome MS, type 2448, provided excellent imagery for delineating most SAV beds which occurred at densities ranging from <1 plant per m^2 to over 1000 plants per m^2. Quality assurance guidelines addressing tidal stage, plant growth, sun elevation, water transparency, atmospheric transparency, turbidity, wind, sensor operation and plotting were found necessary to achieve maximum delineation of the SAV beds.

A total of over 84,000 hectares of SAV were located, mapped and outlined onto 27 topographic quadrangles located in the saline portions of Virginia's section of the Chesapeake Bay. Two species, *Zostera marina* and *Ruppia maritima*, were found to be the dominant vegetation in this region. However, speciation within the beds was not possible at the altitudes flown. The largest concentrations of these species were found at the mouths of the large rivers and creeks and along the Chesapeake Bay shoreline. The most significant areas were: 1. along the western shore of the Bay between Back River and the York River; 2. around the shoreline of Mobjack Bay; 3. throughout the shoal areas east of Tangier and Great Fox Islands; 4. behind large protective sand bars near Hunger's Creek and Cherrystone Creek along the Bay's eastern shoreline. Comparisons of imagery obtained during the summer and early winter periods reflected the natural, late summer die-back of *Zostera* and *Ruppia*. Only the densest areas of vegetation on the summer imagery were generally evident on the winter imagery with reductions in coverage for two areas ranging from 40 to 83%.

Mapping of SAV located within four selected topographic quadrangles along Virginia's freshwater and oligohaline regions, revealed 137 hectares of submerged vegetation. These areas contained a large number of species such as: *Vallisneria*, *Zannichellia*, *Ceratophyllum* *Najas*, *Potamogeton*. In general, the SAV in these areas were primarily small, fringing grass beds whose imagery was difficult to observe from the air at the altitudes flown in this study.

A field survey made along the shorelines of the lower Chesapeake Bay and its tributaries revealed twenty SAV species comprising three associations. These species appeared to be distributed throughout the estuary based primarily upon the species' salinity tolerances. *Ceratophyllum* and other species were found along the freshwater areas of

Virginia's rivers. Areas of low salinities were vegetated with Zannichellia, Potamogeton, etc. while the areas of highest salinities, primarily along the Bay shoreline, were dominated by Zostera and Ruppia. Species richness was inversely related to the apparent salinities, with the low salinity areas having the greatest number of species and the high salinity areas the fewest.

Transects conducted across six vegetated areas found Virginia's Chesapeake Bay shoreline revealed a co-dominance by two species, Zostera and Ruppia. Distribution within these beds appeared to be a function of two factors, site exposure and water depth. Ruppia was dominant in the shallow, more protected areas while Zostera was more abundant in the deeper more exposed sites.

Analysis of the historical distribution of SAV throughout the lower Bay over the last 40 years revealed relatively low levels of SAV in 1937. This situation reflected the documented demise of Zostera in the early 1930's. From 1937 to 1950 the coverage by SAV increased significantly with continued increased coverage observed until the 1960's. High levels of SAV in 1971 were followed by a precipitous decline between 1973 and 1974. This decline continued until 1978 when, apparently, the lowest levels in SAV over the last 40 years were recorded. Areas of greatest recent decline were observed in the lower portions of the major rivers where in 1978 little significant SAV existed. The western portion of Virginia's Chesapeake Bay shoreline north of the York River also experienced a considerable reduction in coverage.

SECTION 3

RECOMMENDATIONS

1. Because SAV communities in the lower Bay are not static but dynamic systems that undergo both seasonal as well as annual changes in abundance, it is felt that imagery should be obtained over the next few years on an annual basis depicting maximum standing crop of all SAV areas. This would be of significant value because: 1. Interest in the status of Bay SAV communities by the general public as well as state and Federal agencies is currently very high; 2. SAV communities are at a very low coverage compared to past years, and up to date information is needed to document any continuing decline or rate of recovery; and 3. EPA's current funding of other SAV research programs will provide results that could be correlated with this distribution and abundance data. Obtaining imagery on an annual basis would provide those data necessary for deciding whether monitoring should be continued on an annual, biennial or less frequent basis. The costs to simply acquire the imagery for Virginia's portion of the Bay would be minimal, and the imagery thus obtained would be available for use by the many agencies concerned with managing this valuable resource.

2. It is important to stress that any imagery obtained for mapping SAV communities be acquired under the constraints of tidal height, sun angle, wind conditions, etc. that have been outlined by EPA for this current project. Attempts to coordinate the acquisition of SAV imagery with other programs requiring aerial photography, such as land use planning, that do not require similar constraints should consider these conditions or will most likely result in aerial photography unsuitable for accurate delineation of SAV communities.

3. It is recommended that altitudes of 3740 m be used for the acquisition of the imagery of SAV communities with a mapping camera. This results in a scale which allows a direct comparison to the standard topographic quadrangle (1:24,000). It also allows complete mapping of most SAV areas except for those minute areas in the freshwater and oligohaline systems where SAV beds are found fringing the marshes. Species determination at this altitude is difficult-if not impossible, and therefore not advised. Lower altitudes (1000 m) may yield the species information, and if necessary, studies could be directed along this avenue of research.

In addition, it is recommended that because of the extensive die-back of SAV throughout the lower Bay during winter months only one mapping flight be made per year. This preferably should be made during the early summer to record maximum standing crop of the vegetation.

4. The oligohaline and freshwater portions of selected areas along Virginia's tidal rivers have been shown in this study to contain scattered small beds of SAV that in many cases are not evident on high altitude aerial photography. It is recommended that future field study be conducted in these regions to provide understanding of their distribution, abundance, and resource values.

SECTION 4

MATERIALS AND METHODS

PRELIMINARY AERIAL SURVEYS

To facilitate the planned large scale mapping of submerged aquatic vegetation in Virginia's portion of the Chesapeake Bay and its tributaries, preliminary aerial surveys were made of these areas in early June, 1978. The flights provided an overview of where current beds of SAV exist and located specific areas for intensive surface measurements. Overflights were made using a single engine Dehavilland Beaver Aircraft at altitudes ranging from 300 to 200 m. They were conducted at times when weather and tide conditions allowed for maximum viewing of SAV beds: low tide, minimal cloud cover, and reduced wind conditions.

Prior to these preliminary overflights, available information on the distribution of SAV beds in Virginia was reviewed. Previously known bed outlines (Orth and Gordon, 1975) were drawn on 1:80,000 maps which were then carried inflight and additions or deletions were made as necessary to determine a preliminary qualitative identification of existing SAV coverage. This information was then used to prepare flight lines for the aerial mapping, to assist in delineating areas for transect analysis and for historical review of changes in SAV distribution.

MAPPING OF SUBMERGED AQUATIC VEGETATION

The method of mapping submerged aquatic vegetation is graphically depicted in Figure 1. The method consists of acquiring photography, transferring the SAV perimeter information from the photography to maps, measuring individual SAV bed areas, and compiling the data into a computer data base. Each component of the procedure is more fully described below.

Aerial Photography

The first phase of the aerial photography effort was the planning of flight lines for complete coverage of all anticipated areas of SAV in the Virginia portion of the Chesapeake Bay. Preliminary aerial surveys for visual observations only were conducted as described above. Flight lines for photography were then planned for coverage of all areas where SAVs were seen during the aerial surveys or known from prior study. Flight lines were drawn on 1:250,000 scale USGS topographic sheets, 2^{o} by 1^{o} series, using a transparent frame-size overlay for coverage at a minimum altitude of 2740 m (9,000 feet). Flight lines were situated to ensure both complete

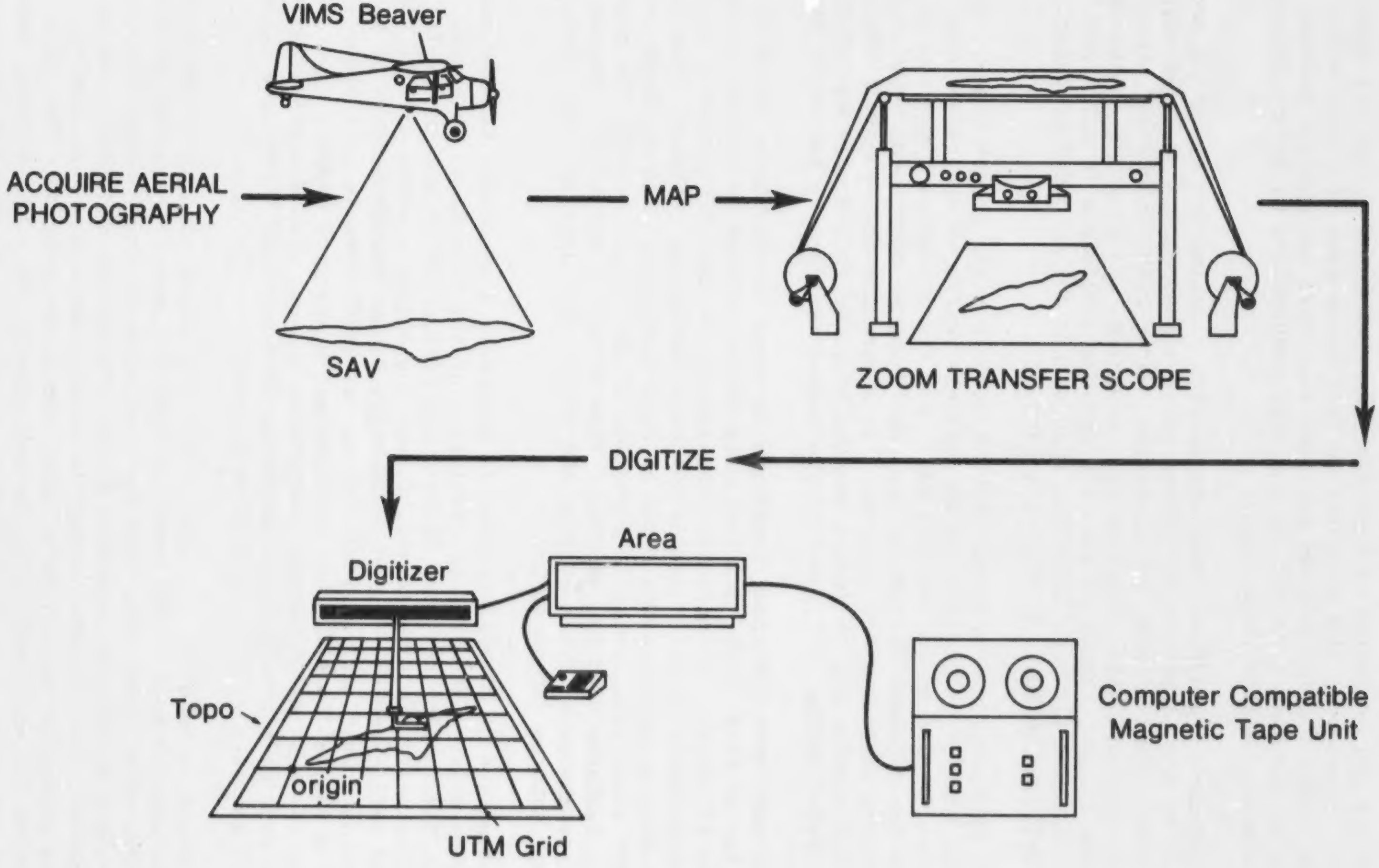
VIMS Beaver
ACQUIRE AERIAL PHOTOGRAPHY
SAV
MAP
ZOOM TRANSFER SCOPE
DIGITIZE
Area
Digitizer
Topo
origin
UTM Grid
Computer Compatible Magnetic Tape Unit

Figure 1. Transfer of SAV distribution information from photography to computer tape.

bed coverage and inclusion of land features as control points for mapping accuracy. Lines were also oriented to facilitate ease of flying where possible. Flight direction was oriented such that the overall mission would progress in the same direction as the tide propagation to ensure photography at the lowest possible tidal stage.

The general guidelines used for mission planning and execution were developed by EPA (Appendix A). These quality assurance guidelines address tidal stage, plant growth, sun elevation, water transparency and atmospheric transparency, turbidity, wind, sensor operation, and plotting. Although it was the overall intent to plan for optimum conditions in all items, some are necessarily more important than others and an order of priorities was established to guide mission planning.

The most critical of those items listed is plant growth stage. At the wrong time of year, it would be possible to fly an otherwise ideal mission and record no (or little) SAV. For the predominant species of grass in the southern Chesapeake Bay, early summer offers the best chance of recording maximum plant coverage. To ensure the most complete distribution information and to record seasonality, the entire area was photographed twice during 1978, once in the summer and once in the early winter.

The next most important condition is water transparency, which is itself a function of wind, tide, and turbidity (often related to weather during the previous 12 hours). Atmospheric transparency is important since a high sunlight-to-skylight ratio yields the best SAV-bottom contrast. Sun elevation is also a consideration since at high elevations (sun too high in the sky) sun glint will appear in a portion of the frame, masking the grass or other features used for mapping. This effect is minimized, however, by the proper choice of frame overlap and flight line sidelap. Sun elevations were kept between 25° to 45°.

The choice of flight altitude is generally a trade-off between areas covered by a frame and spatial resolution of the objects of interest. In previous SAV mapping reported in Orth and Gordon (1975) and in special film-filter-altitude experiments, it was found that a scale of 1:30,000 provided sufficient resolution to identify dense 1-meter patches of grass. The maximum operational altitude for the aircraft used in this operation is 3660 m (12,000 feet). This altitude and a standard mapping camera with a 152 mm (6-inch) focal length lens yields imagery with a scale of 1:24,000. Flights were made at altitudes as low as 2740 m (9,000 feet) to a scale of 1:18,000 when atmospheric conditions dictated.

Aircraft scheduling was done in advance around windows in the morning and afternoon (2 to 3 hours) near low tide for specific regions in Chesapeak Bay. NOAA tide tables were used for prediction of tidal stage throughout the Bay, and a table of suggested flight windows was made for a one to two-month period. For flights during the summer, the times from 1100 to 1300 EDT were generally avoided to minimize sun glint problems. The actual decision to fly on a particular day was made in the early morning, based on forecasts of regional weather systems, previous local weather (24 hours), and most important, current conditions. Because of weather variation, it was generally not possible to pick an "ideal" day for aerial photography in advance.

The camera used for all aerial photography of SAV was a Fairchile CA-8 cartographic camera with a 152 mm (6½-inch) focal length Bausch and Lomb Metrogon lens. Film was Kodak 24 cm (9½-inch) square positive transparency Aerochrome MS, type 2448, loaded into magazines in advance. The camera was mounted in a camera port in the belly of the VIMS single-engine, fixed high wind DeHavilland Beaver aircraft. The aircraft provides a stable platform for vertical aerial photography from 300 to 3700 m altitude (1,000 to 12,000 feet).

The camera was checked for vertical orientation before each exposure, using two-axis levelling. Exposures were timed to insure 60 to 65% forward lap (standard frame spacing), and times were adjusted according to flight line direction in relation to winds aloft. Where adjacent parallel lines were flown, 30% sidelap was planned to insure mapable quality contiguous coverage. A Wratten 1A haze filter was used inside the cone of the camera to reduce the degrading effect of atmospheric haze on image quality.

Personnel on the aircraft during a mission included a pilot, navigator, and a camera operator. While in the air, the navigator recorded notes as to atmospheric conditions, flight line number, altitude, heading, frame count, camera setting, and any unusual observations on cassette tape with a portable battery-operated recorder. The navigator signaled line start and line stop and watched for flight line drift (making suggested corrections to the pilot) during photography. The navigator was also experienced in the recognition of SAV areas and modified flight lines or added more lines during the mission to ensure better or more complete coverage.

Color film was chosen for this project since it offers adequate information for delineating SAV beds and a great amount of general information for use in other projects by EPA, VIMS and other agencies. When not used in the aircraft, film was kept refrigerated. Following exposure the 38 m rolls were flown to the EPA-EPIC facility for immediate processing in a continuous roll Kodak 1411 processor. Each roll contained some test exposures to permit selection of optimum transport speed and temperature during processing. A duplicate copy was made for data extraction while the original was retained (after screening) for archival purposes by EPIC. Film was generally returned to VIMS the same day as processed. At the VIMS Remote Sensing Center, the film was carefully reviewed for quality and adequacy of coverage and entered into the Center's photo-index system. Cassette photo-logs were transcribed to typed hard-copy and checked against the film. Based on this information, areas were selected for recoverage where sun glint or other problems dictated.

Mapping Process

Before mapping the film was reviewed by a photointerpretor and a biologist to select individual frames for best SAV coverage. The SAV beds were identified using all available information, including knowledge of aquatic grass signatures on the film, areas of grass coverage from previous flights, ground information, and aerial visual surveys. In areas where the SAV/bottom contrast was poor, the grass boundary was delineated using a fine point pencil on transparent tape placed on the film. This was done to aid in transferring the imagery on the film to the topographic quadrangles using the Zoom Transfer Scope. Extreme care was exercised to ensure the tape was put on the non-emulsion side of the film in a manner which will allow it to be easily removed at a later time. An estimate of percent cover within each seagrass bed was made visually in comparison with an enlarged Crown Density Scale similar to those developed for estimates of forest tree crown cover from aerial photography (Figure 2). Bed density was classified into one of four categories based on an objective comparison with the density scale. These were: 1. very sparce, (<10%); 2. sparce (10 to 40%); 3. moderate (40 to 70%); or 4. dense (70 to 100%). Either the entire bed, or sub-sections within the bed, were assigned a number (1 to 4) corresponding to the above density categories.

A Bausch and Lomb Zoom Transfer Scope, model ZT-4H, was used to trace the delineated SAV bed boundaries from the aerial photography to base maps of 1:24,000 scale USGS paper topographic (7½-minute series) quadrangles. The Zoom Transfer Scope enables the operator to view the photograph and the map simultaneously, adjust scale, rotate, and translate one in relation to the other optically, and draw the bed outlines and grass density information directly onto the base map. Non-changing features common to the imagery and the topographic quadrangle, such as road intersections, houses, creeks, ets., were used for alignment and scaling purposes. After transfer of the bed outlines onto the base maps the maps were reviewed with the aerial photography to insure accurate coverage. The original paper topographic quadrangles have been filed at VIMS for future reference. Translucent mylar stable-base topographic quadrangles were placed over the original base maps, and SAV bed outlines and density information were transferred with black ink. These maps were then photo-reduced and are included in Appendix B of this report. The full-size mylar quadrangles have been filed with EPA.

Area Measurement

Areas of SAV beds were derived from the 1:24,000 scale topographic quadrangles. Measurements were made on a Numonics Graphics Calculator, model 1224. The unit has a resolution in x and y of 0.25 mm and has registers for scaling and unit conversion so that areas can be read out in any units desired at map scale. Accuracy, determined by repetitive measurement of test areas, is better than 2%. Precision (standard deviation divided by the mean) ranges from approximately 2% at 16 mm^2 (10,000 m^2 at a scale = 1:24,000) to well under 1% at 160 mm^2 (100,000 m^2) with an overall average of 1.4%. Areas on each topographic quadrangle were summed and tabulated (Table 2).

Data Base

To enable computer retrieval of areal resource information and comparison of different aspects of one or more resources over time, a data base structure has been created. All the information from the 1978 SAV mapping effort has been entered into this data base. The geographical coordinate

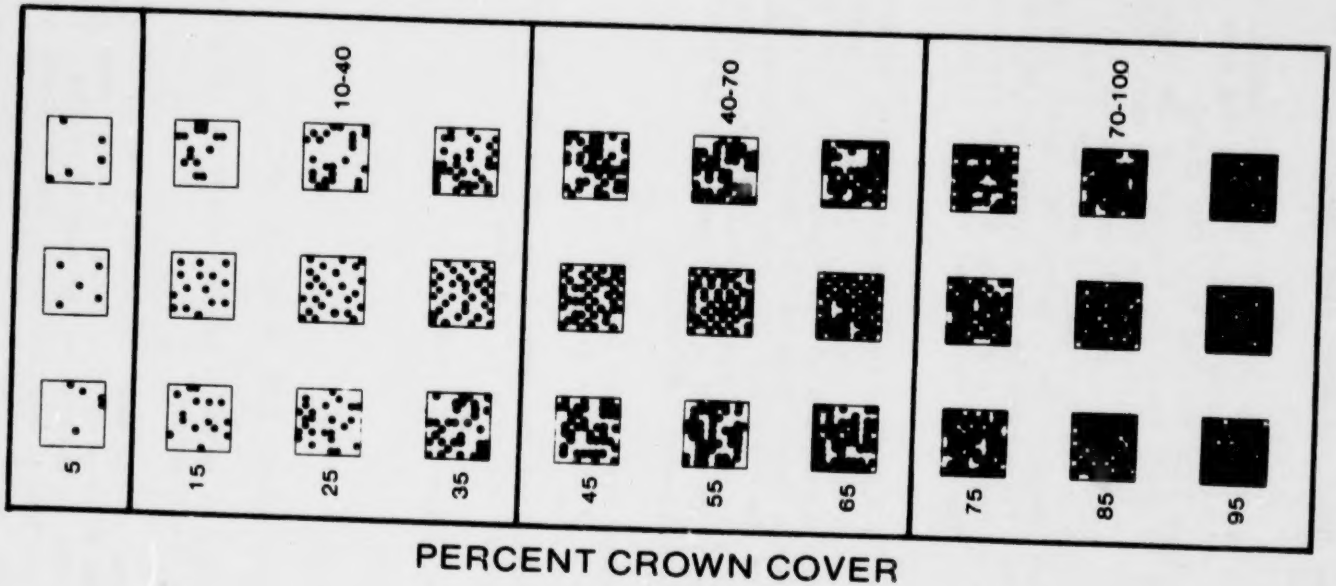
5
15
25
35
10-40
45
55
65
40-70
75
85
95
70-100
PERCENT CROWN COVER

Figure 2. Crown density scale used to estimate SAV percent cover.

system for the data base is the Universal Transverse Mercator coordinate system (UTM). It is anticipated that other information summarizing areal resources, such as oyster bar areas and marsh distribution, could easily be entered into the data base.

The grid base for the areal data is the 1,000 m square defined by UTM easting and northing (x and y) coordinates found along the edge of each 7½-minute topographic sheet (the base map for this SAV study). In order to enter any areal data into the data base, the outline of the resource is drawn on a topographic map, as has already been done in this study for 1978 SAV beds. A clear grid containing 1,000 m lines drawn at a 1:24,000 scale is then placed over the base map and aligned with the 1,000 m UTM grid marks. The two are then taped to the Graphics Calculator table, and the areal data is transferred grid-square by grid-square to computer compatible magnetic tape (CCT using both the digitizing and area measurement functions of the Calculator. The lower section of Figure 1 illustrates this step.

The Graphics Calculator contains an integral microprocessor which controls the format of information sent to the CCT. For each topographic sheet a master header is used consisting of the topographic sheet quadrangle name, the Virginia alphanumeric index, date of the survey, and the UTM coordinates of the origin of the digitizer (Graphics Calculator) coordinate system. The digitizer x-axis is always electronically aligned with the UTM easting axis. For each 1,000 m grid square there is a 7-field data block sent to tape with the following information:

field 1 = UTM coordinates divided by 100,000 m (2 digits - x, 2 digits - y),

field 2 = UTM coordinates for the lower left corner of the 1,000-meter square (2 digits - x, 2 digits - y),

field 3 = topographic alphanumeric index,

field 4 = waterway code,

field 5 = resource code,

field 6 = resource area within 1,000 m square, and

field 7 = x, y coordinates in mm of the perimeter of the resource for replotting the boundary.

Field 1 generally remains the same throughout a topographic quadrangle (unless field 2 approaches 99 in x or y). Field 3 is the same alphanumeric topographic quadrangle index as entered in the master header. Field 4 is a 5-digit code for a particular bay, river, or creek within the Chesapeake Bay estuary as used by the United States Corps of Engineers, Norfolk District, and the State of Virginia. Field 5 is a 5-digit code to describe the resource being digitized. The first digit is the resource type. S for SAV is the only type considered thus far. The second digit is the season of data acquisition (a number from 1 to 4 for each 3-month quarter). The third digit is the salinity regime (1-saline, 2-brackish, 3-fresh, 4-euhaline >24°/oo, 5-polyhaline 18 to 24°/oo, 6-mesohaline 5 to 18°/oo, 7-oligohaline .5 to 5°/oo). The last two digits indicate the species, community type, or other classification to define the resource. Fields 2, 6, and 7 change for each 1,000 m grid square. Fields 3, 4, and 5 are changed when necessary.

An example of the data base for SAV beds is shown in Figure 3 and Table 1. Figure 3 illustrates the outline of a grass bed with the 1,000 m grid overlay in place. Several of the grid crossings have been numbered (e.g. 68,72 corresponds to 68,000 m E, 72,000 m N). Information from the shaded area would be put into the data base as shown in Table 1.

No computer programs to access the data base have been written at present. The information in the data base, however, has been structured for ease of information retrieval, and simple programs could be written in minimal time to access all of the information using fields 1 through 5 as search keys. In addition, the area perimeter has been digitized and the x - y coordinates stored so that partial or complete resource boundaries could be plotted either on a television type computer terminal or simple x - y plotter. The computer tape (CCT) containing the data from the 1978 SAV mapping effort is on file in the VIMS computer center and is available upon request.

It is anticipated that SAV information in this format will be of great utility to managers, decision makers, scientists and others, all of whom may need current and historical SAV resource information in a concise, quickly accessed form.

FIELD SURVEYS

The distribution of SAV in Virginia can be divided into at least two distinct zones: Zostera and Ruppia forming large beds in the polyhaline (18-24°/oo) and mesohaline areas (5-18°/oo), and Vallisneria, Potamogetons, Zannichellia, etc. comprising lesser but generally undetermined amounts in the oligohaline (0.5-5°/oo) and freshwater areas (<0.5°/o). Because of this, several approaches were used to gather surface information to assist the aerial photography in zone delineation.

At locations within the oligohaline and freshwater zones (in Virginia these fall wholly within the tidal rivers) where the preliminary overflights revealed observable beds of SAV, field checks were made by use of small boats to determine species present, relative abundance and habitat type (Figure 4). In addition, these areas were mapped using remote sensing techniques described in the preceeding section and the results displayed on USGS topographic quadrangles (7.5 minute series).

In the mesohaline and polyhaline zones (comprising Virginia's portion of the Bay proper and the lower sections of its major tributaries) a similar survey was undertaken (Figure 4). In this region the beds are generally large, well defined, and under appropriate conditions easily seen from the

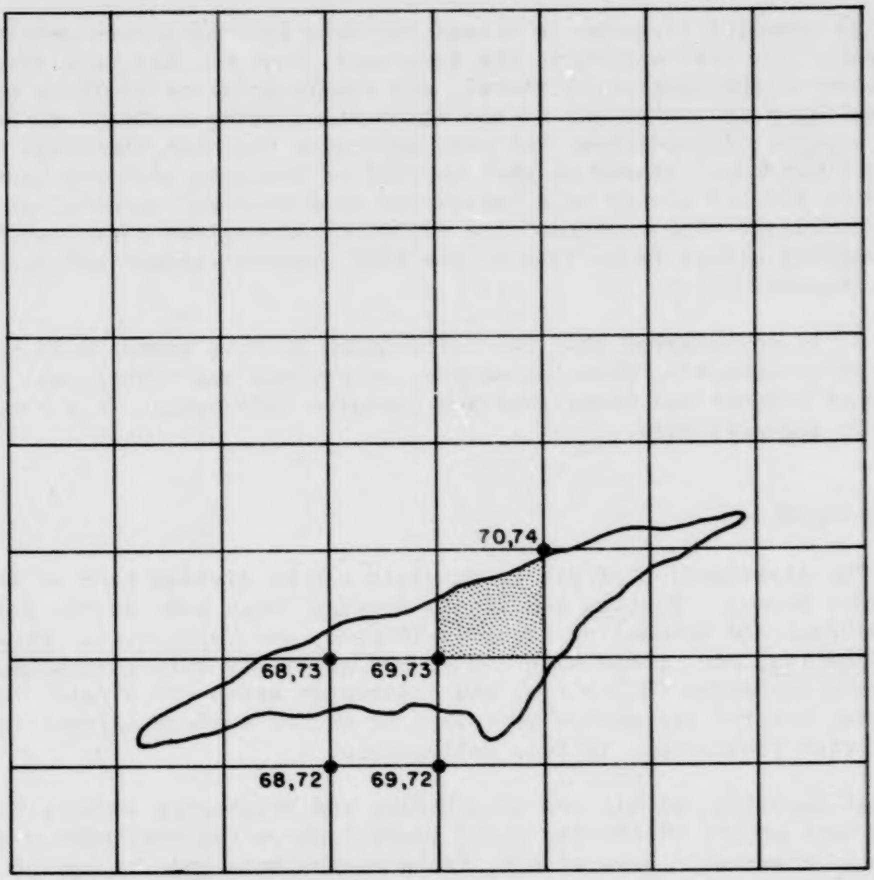
70,74
68,73
69,73
68,72
69,72

Figure 3. Example of SAV bed on a base map with 1000 meter grid overlay. Coordinates are in thousands of meters.

TABLE 1. COMPUTER DATA BASE INFORMATION STORED ON MAGNETIC TAPE FOR A SINGLE 1,000-METER GRID SQUARE

Field	1	2	3	4	5	6	7
Data	0341	6973	002	YORO1	S3501	693	X,Y,X,Y,X,Y,etc.

1. UTM coordinates for topographic sheet (stays the same, generally, throughout topographic sheet).
   300000 m E, 4100000 m N

2. UTM coordinates for 1,000 meter square.
   69000, 73000

3. Topographic sheet code, 002 = Achilles Quadrangle.
   (7.5 min. sheet)

4. Waterway code (used by the Norfolk Corps of Engineers and State of Virginia).
   YORO1 = York River

5. Resource code.
   S = type = SAV
   3 = Season = July, August, September
   5 = Salinity = polyhaline
   01 = Community, etc. = Zostera, Ruppia

6. Area in square meters per 100.
   693 = 69,300 m^2

7. x, y - coordinates of perimeter of resource area for replotting.

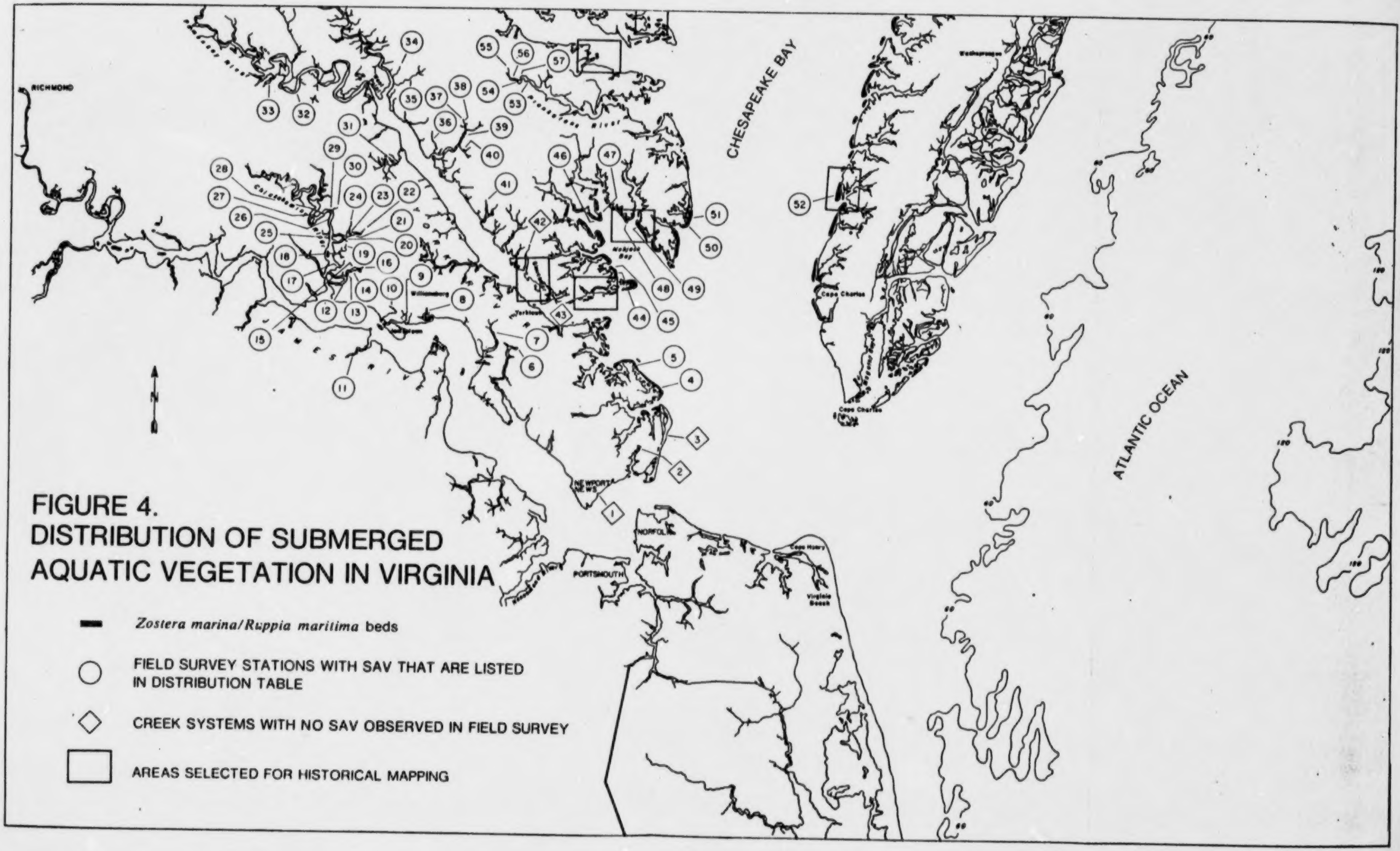
RICHMOND
CHESAPEAKE BAY
ATLANTIC OCEAN
NORFOLK
PORTSMOUTH
NEWPORT NEWS
Williamsburg
Yorktown
Mobjack Bay
Cape Charles
Cape Henry
Virginia Beach
N
1
2
3
4
5
6
7
8
9
10
11
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FIGURE 4.
DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION IN VIRGINIA

▬	*Zostera marina/Ruppia maritima* beds
○	FIELD SURVEY STATIONS WITH SAV THAT ARE LISTED IN DISTRIBUTION TABLE
◇	CREEK SYSTEMS WITH NO SAV OBSERVED IN FIELD SURVEY
▭	AREAS SELECTED FOR HISTORICAL MAPPING

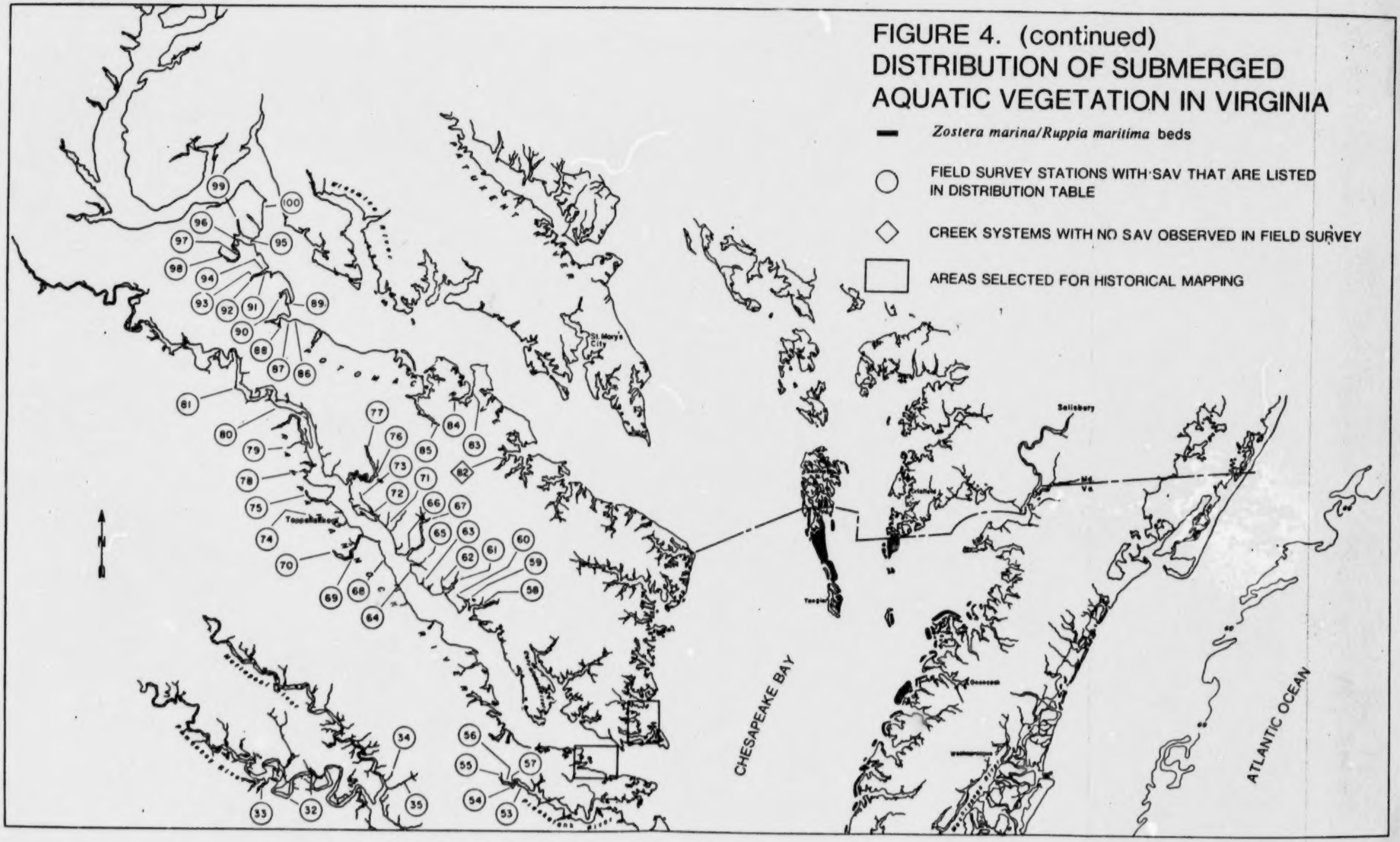

FIGURE 4. (continued)
DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION IN VIRGINIA

▬ *Zostera marina/Ruppia maritima* beds
○ FIELD SURVEY STATIONS WITH SAV THAT ARE LISTED IN DISTRIBUTION TABLE
◇ CREEK SYSTEMS WITH NO SAV OBSERVED IN FIELD SURVEY
☐ AREAS SELECTED FOR HISTORICAL MAPPING
PATUXENT
POTOMAC
St. Mary's City
Salisbury
MD
VA
Tangier
Onancock
Wachapreague
Tappahannock
CHESAPEAKE BAY
ATLANTIC OCEAN
N
99
100
96
95
97
98
94
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81
77
84
83
80
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air. It is this zone that has been the major focus of aerial mapping effort by this study.

Other selected areas where submerged vegetation was not evident from the air were also field checked to determine if SAV were indeed present (Figure 4). An attempt was made to investigate several areas along the salinity gradient in each of the major tributaries, since it is known that salinity is one of the main factors controlling species distribution throughout the Bay (Stevenson and Confer, 1978). Segments of shoreline along both the major rivers and creeks were surveyed by use of a small boat and samples obtained with a rake or collected by hand. The procedure involved slowly moving along the littoral zone and simply observing the water for signs of SAV presence or repeatedly raking the bottom in the most turbid areas for evidence of SAV. A 0.5 m periscope was used on occasion to view below the water surface. In those creek systems surveyed, an attempt was made to go upstream as far as possible into the head of the numerous marsh guts which are common throughout these areas. Personnel from the VIMS' Wetlands Department assisted in this survey while simultaneously conducting their state marsh inventory.

Locations of SAV were recorded on USGS topographic quadrangles (7.5 minute series; 1:24,000 scale). Areas of SAV were designated as mapping units. A mapping unit consisted of one of the following: a large bed; a narrow or intermittent fringe along a shoreline; a pocket area at the head of a marsh gut. For each mapping unit, species presence and relative abundance of each species were recorded. General observations on habitat were also made including the associated marsh vegetation. Representative samples were collected and returned to the laboratory for further species identification according to Gray's Manual of Botony, 8th Edition. Voucher specimens were pressed and mounted for herbarium storage.

To display species associations between mapping units, Dice's (Boesch, 1977) index of co-occurrence was calculated. Cluster analysis was performed using group average sorting (Lance and Williams, 1967) with the COMPAH Program (Boesch, 1977) on an IBM 370-15 computer. Dendograms were then constructed to distinguish significant groupings of SAV species.

TRANSECT ANALYSIS

In addition to the above field survey, the distribution of species within selected, large SAV beds in the mesohaline and polyhaline zone were investigated by an intensive, transect sampling program. Six areas along both the eastern and western shore of the lower Chesapeake Bay were selected for analysis after review of both current and historical aerial photography and surface information data. These areas (western shore: Plum Tree Island, Browns Bay in the Mobjack Bay, Ware Neck Point, Mouth of the East River and Horn Harbor; eastern shore: Vaucluse Shores at the mouth of Hungar's Creek) were representative of the dense areas of SAV presently found throughout the lower Bay. The site selected on the eastern shore was the same site selected for intensive study by the Functional Ecology, and Biology and Propagation Programs also funded by the EPA, Chesapeake Bay Program

The objective of the intensive transect analysis was to provide a more detailed examination of the species composition and plant community zones within these representative beds. In addition, other general relationships between species present, sediment type, depth, distance from shore, relative abundance, and relative importance of the species were investigated.

A line intercept method (Schmid, 1965; Lind and Cottam, 1969; Davis and Brinson, 1976) was chosen for conducting the vegetational analysis because of its ease in locating sampling points, accuracy in measuring distances, and sensitivity to measuring changes along a gradient such as depth. In this method, a 100 m line, marked at 2 m intervals, was run offshore from a permanent reference stake, along a fixed compass bearing to a second stake. Additional stakes and line in 100 m segments continued along this bearing to the offshore limits of vegetation.

A diver equipped with a 0.1 m^2 ring and depth pole graduated to mm, visually observed the SAV along the transect. A 0.1 m^2 sample size was chosen because the limited number of species expected, the high density of the vegetation (greater than 1000 shoots per m^2) and poor visibility due to high turbidity (Secchi disk <1 m). At 10 m intervals the sampling ring was placed on the bottom and the following data were recorded on polystyrene tablets: time, distance from shoreline, depth (cm), species presence and percent cover of each species, bottom type, and general observations noted over the last 10 m interval. Initially, two divers made independent observations of the percent cover to test the adequacy of the sampling and provide quality assurance for the data collected. These initial tests established that one diver could accurately describe the species present and species abundance.

A reference tidal staff graduated in mm was placed along the transect at a bottom where the depth was estimated to be greater than mean low water (MLW). Time and water depth (cm) were recorded at this reference stake at 15 minute intervals throughout the duration of the transect sampling. The tidal staff data served to relate data collected during the transect analysis with tidal data available from NOAA tidal charts. From this, the relationship between species presence and abundance could be related to true mean low water.

Salinity samples were taken and temperature measurements made at each transect. Temperature was recorded with a bulb thermometer and salinity samples analyzed with an induction salinometer located at the VIMS laboratory.

Percent cover was used as an indicator of abundance since it allowed a large number of observations to be made while processing of standing crop samples could be held to a minimum. Because of the few species present and the ability of percent cover estimates to delineate community zones (Wikum and Shanholtzer, 1978), it was felt that adequate information would be provided by this method. To determine correlation between percent cover and standing crop, a limited number of samples were taken at 50 m intervals along the Vaucluse Shores transects. After percent cover estimates were made of each of these 0.1 m^2 quadrats, the entire 0.1 m^2 quadrat including above ground and below ground portions of the SAV's were removed from the bottom and placed in a fine mesh bag. The bag was then washed to remove most of the sediment, and the contents transferred to a plastic bag for later analysis.

Harvested samples were divided into species and separated into above ground plant material, and roots and rhizomes. The plants were then counted, dried to a constant weight and weighed to the nearest 0.01 g. Product moment correlations (Sokal and Rohlf, 1969) were calculated between percent cover; number of shoots per 0.1 m^2 ; and above ground, below ground and total weights of each species. Comparisons were also made with the more complete seasonal standing crop data obtained at the Vaucluse Shores site for other projects.

Relative importance of the various plant species within each transect was illustrated by calculating importance values (Wikum and Shanholtzer, 1978) utilizing the percent cover data. Means, ranges and maximum depths of occurrence were also investigated.

Description of vegetation-environmental relationships along the transects was illustrated by the use of profile diagrams. Each profile diagram presents the bottom topography from shore to the offshore limits of plant growth in either a right-left of left-right direction depending upon the appropriate orientation of the SAV beds on a topographic sheet. Percent cover information for each 10 meter observation was presented by use of bargraph so that one can simultaneously visualize species cover, community composition and vegetation-topographic relationships.

Bottom elevations relative to mean low water (MLW) were calculated along each transect by a method of simultaneous comparisons similar to that method described by Boon and Lynch (1972) for the Elizabeth River, Virginia. Basically, the method is a leveling procedure in which the intervening water surface between two tidal stations during the same phase of the tide is assumed to act as a level plane for the transfer to tidal information. In this study, the VIMS tidal station located on the York River, served as a reference for each comparison. For each transect profile, MLW on the adjacent reference staff was calculated by the following based on Figure 5:

Given: h, h_2, h_3

If: $h_1 = h_3$

Then: $\mathrm{MLW} = h_2 - h_1$

It is assumed that the sea's surface will not always act as a level plane and therefore increasing the number of comparisons made during periods of similar tidal phases (i.e. high water on low water) would increase the precision of the calculation of MLW for each transect reference staff. Boon and Lynch (1972) found, however, that as long as the compared tidal stations are subject to the same tidal influences, variations in the calculated MLW heights would be minor. They found that results corrected to within 0.1 foot could be obtained when a full month of data was used.

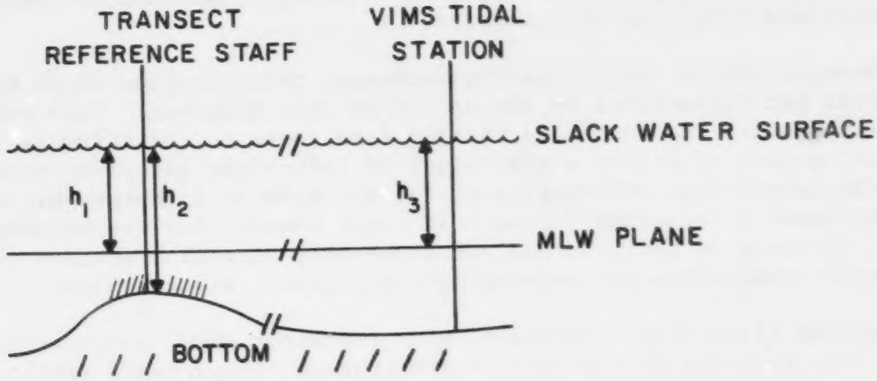

TRANSECT REFERENCE STAFF
VIMS TIDAL STATION
SLACK WATER SURFACE
h_1
h_2
h_3
MLW PLANE
BOTTOM

Figure 5. Relationship between transect reference staff and VIMS tidal station.

In this study, only one or two slack water periods were available for comparisons. Therefore, error in calculations of MLW could be greater than 0.1 ft. However, since the transect stations involved in this study are in close proximity to the VIMS station, have slack water periods within one hour of the VIMS station and have approximately the same tidal ranges (NOS Survey, 1978), it is likely, based on Boon and Lynch's work, that the MLW determinations are accurate to within 0.2 ft. or 0.6 diameter (dm). For comparisons between transects therefore, all elevations are rounded to whole dm.

Bottom elevations relative to calculated MLW were determined along each transect by comparisons with the adjacent reference staff as follows:

C	=	B	-	A
Transect point elevation relative to MLW		Transect point water depth at time t		Difference between tidal height on staff at time t and MLW on staff

Refer to Figure 6.

To determine "A" in the above equation the portion of the tidal curve covering time on site at each transect was plotted using the observed 15 minute reference staff tidal heights. An instantaneous tidal height for time (t) was then interpolated from this graph (Figure 7).

For example, if at time t the measured water depth at a sampling point 330 m from shore along a transect was 2.0 m and at the same time t the tidal height at the adjacent reference stake was calculated to be 1.0 m above MLW, then the bottom would lie,

$$-2.0\text{m} + 1.0\text{m} = -1.0\text{m}$$

or, 1.0 m below MLW at the 330 m sampling point.

ANALYSIS OF HISTORICAL SAV DISTRIBUTION

Six areas were examined for changes in the distribution of SAV over approximately the last 40 years (Figure 4): two locations, Guinea Neck and Mumfort Island, the York River; one in Mobjack Bay at the mouth of the East River; one in the Rappahannock River; one on the western shore in Fleets Bay; and one along the eastern shore of the Bay just north of Hungar's Creek. These areas were selected after review of many historical photographs covering Virginia's entire Bay shoreline as well as the lower portions of each of the major tributaries since 1937. They are thought to be representative areas demonstrating the changes in the *Zostera marina* and *Ruppia maritima* dominated SAV beds found throughout this region.

Aerial photographs available through the U.S. Geological Survey, U.S. Department of Agriculture-Soil Conservation Service, National Oceanic and Atmospheric Administration and the Virginia Department of Highways were

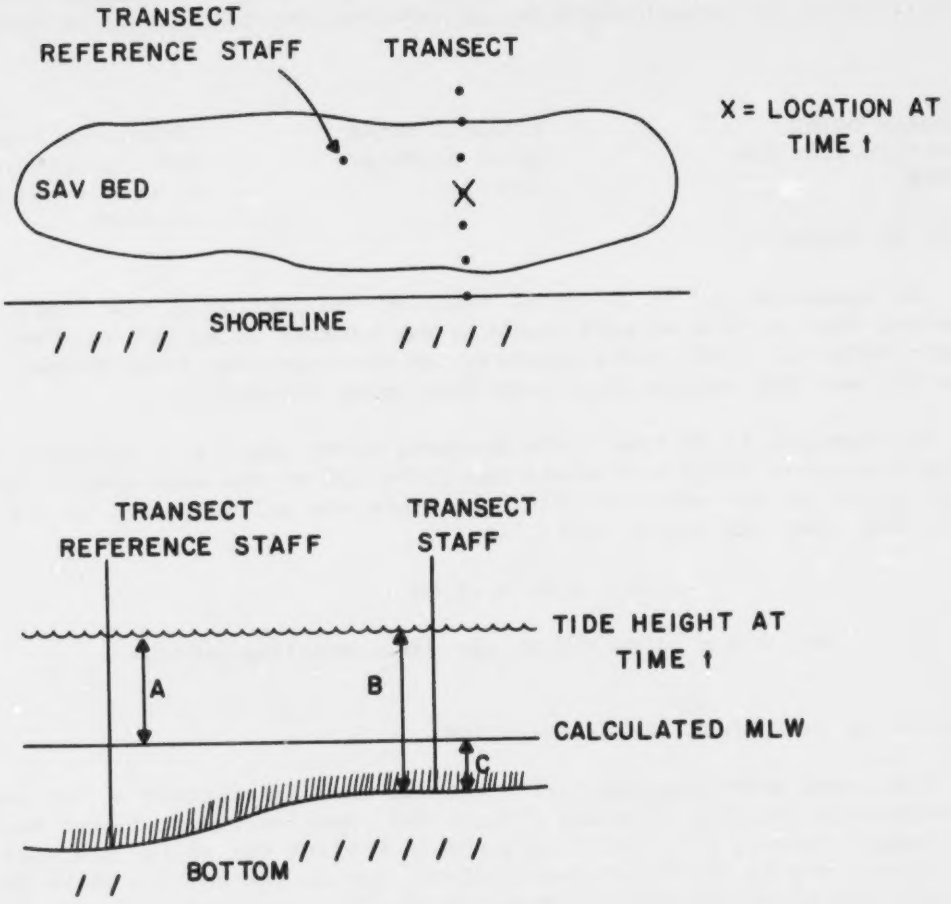

TRANSECT
REFERENCE STAFF
TRANSECT
X = LOCATION AT
TIME t
SAV BED
SHORELINE
TRANSECT
REFERENCE STAFF
TRANSECT
STAFF
TIDE HEIGHT AT
TIME t
A
B
CALCULATED MLW
C
BOTTOM

Figure 6. Relationship between transect reference staff and transect staff.

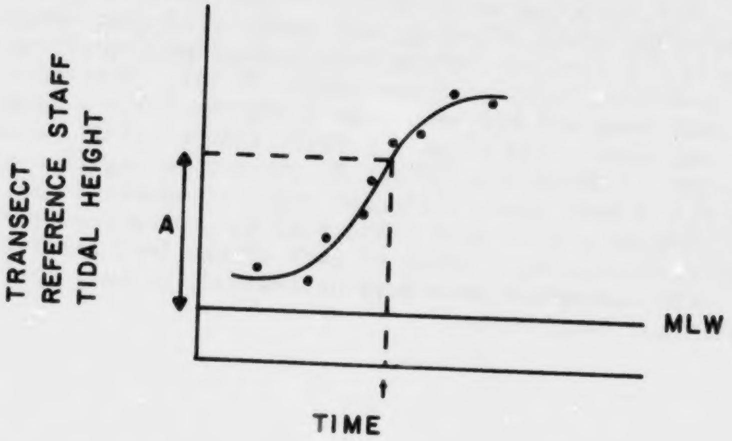


Figure 7. Determination of instantaneous tidal height from calculated tidal curve at time t.

reviewed for scale, completeness of coverage, time of year and apparent water clarity. Because the original photographic overflights were made for purposes other than the mapping of submerged aquatic vegetation, many of the conditions which provide for optimum coverage of SAV were not met. However, good coverage at approximately ten year intervals was obtained.

For the last decade more frequent intervals of coverage were available. Orth and Gordon (1975) had documented the demise of Zostera dominated SAV beds in several areas of Virginia since 1971. Utilizing the aerial photography obtained for that study, each of the selected areas, except for the Eastern shore site, were mapped for SAV coverage in 1974. In addition, the current 1978 coverage is used.

Information from historical photographs documenting the distribution of SAV within each of the six selected areas was transferred to base maps in a manner similar to that employed in mapping the current 22.9 x 22.9 cm (9 x 9 inch), 1978, coverage as previously described. Outlines of the SAV beds were rectified, scale adjusted, and transferred onto United States Geological Survey, 7.5 minute series paper topographic quadrangles using a Bausch and Lomb Zoom Transfer Scope (Model ZT-4H). Estimates of percent cover within each seagrass bed were made using the Crown Density Scale (Figure 2). Bed density was classed as very sparce (<10%), sparce (10-40%), moderate (40-70%) or dense (70-100%). If there were significant differences in density within a bed, these different zones of coverage were also outlined. Areas of SAV coverage within each historical site were measured using a Numonic Graphics Calculator. Areas of each of the four density classifications within each historical site were determined, as well as total area covered by all four categories.

SECTION 5

RESULTS AND DISCUSSION

AERIAL MAPPING

The aerial photography and the subsequent mapping process resulted in the delineation of the significant areas of submerged aquatic vegetation present in Virginia's tidal waters during 1978. These SAV areas are outlined on 31 mylar USGS topographic quadrangles (7.5 minute series) supplied to the U.S. Environmental Protection Agency in partial fulfillment of this grant. Of these 31 topographic maps 27 depict mesohaline and polyhaline areas along both the eastern and western shores of the Bay and, as such, are dominated almost exclusively by a species mixture of *Zostera marina* and *Ruppia maritima* (Figure 8). The remaining four topographic sheets (Mathias Point, Dahlgren, Colonial Beach, Norge) display significant areas of oligohaline and freshwater species found along several sections of the tidal rivers (Figure 8). These 31 sheets do not represent all of Virginia's shoreline but only those where SAV was observed. Reproductions of all these quadrangles are included in Appendix B of this report.

To assist in the visual interpretation of the areas of SAV, zones of similar percent cover within the beds are outlined on each quadrangle with the appropriate numbers indicative of one of the four density classes (1=<10%, 2=10-40%, 3=40-79%, 4=70=100%). Although it is evident to the authors that this technique is subjective, it is believed that this does contribute significantly to the results of the study. Many of the *Zostera* and *Ruppia* dominated beds found throughout the lower Bay are characterized by large areas of sparse coverage (e.g. Parksley, Fleets Bay quadrangles). If these areas were presented as simple outlines, there would be a gross overestimation of the amount of SAV present. In addition, without a density classification scheme those areas which contain very dense stands of submerged grasses (e.g. Franktown, Achilles quadrangles) could not be identified as being of high environmental value.

DISTRIBUTION OF SAV IN MESOHALINE AND POLYHALINE AREAS

Discussion of the distribution and abundance of SAV in the mesohaline and polyhaline regions of the lower Bay where SAV were found is presented below based on major sections of the Bay rather than individual topographic quadrangles (e.g. the York River rather than Clay Bank, Achilles, Yorktown, Poquoson West quadrangles). The total areas of SAV as displayed on each quadrangle are presented in Table 2. In addition, because of the availability of other data from previous surveys (Orth and Gordon, 1975),

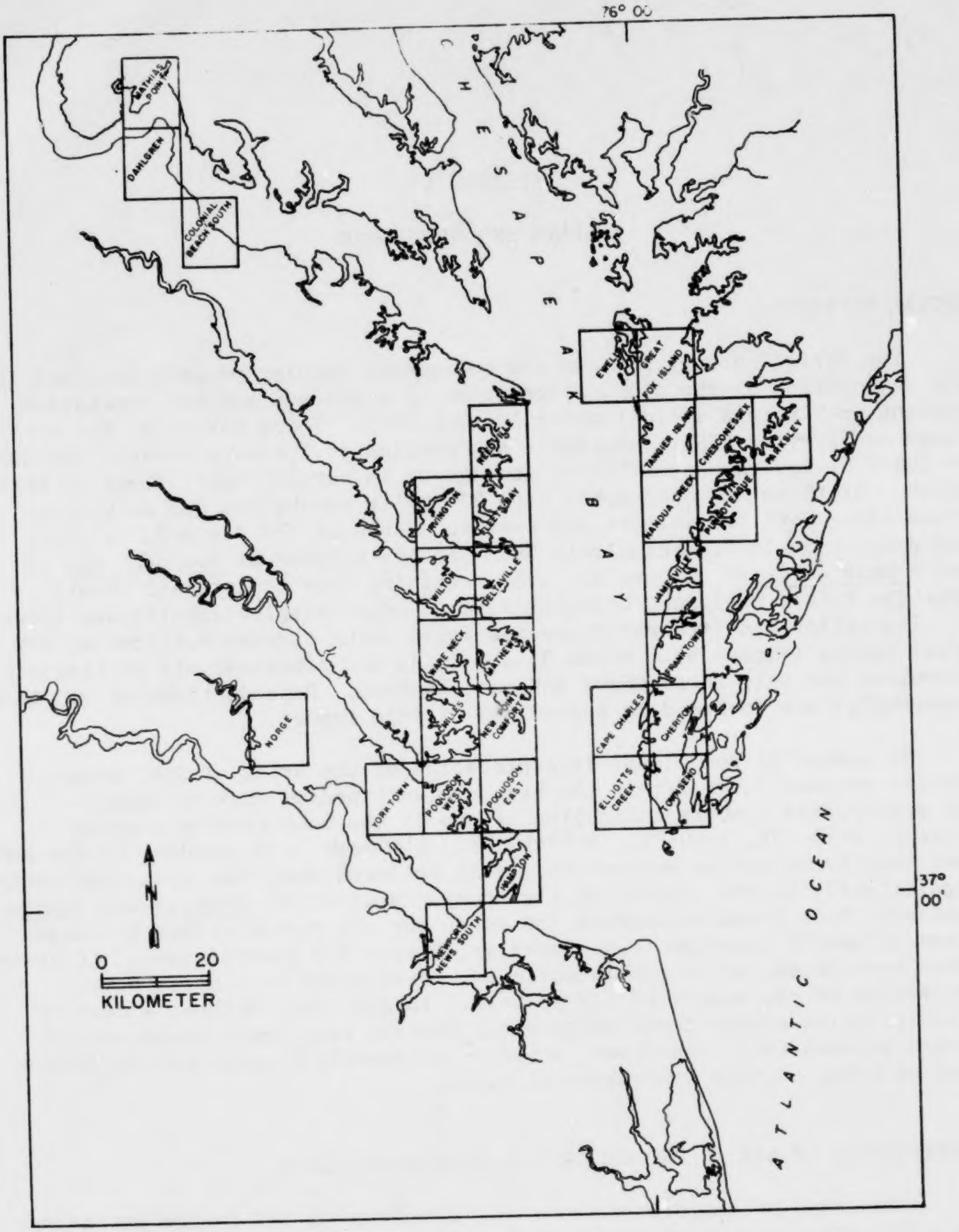

76° 00'
CHESAPEAKE BAY
MATHIAS POINT
DAHLGREN
COLONIAL BEACH SOUTH
EWELL
GREAT FOX ISLAND
TANGIER ISLAND
CHESCONESSEX
PARKSLEY
REEDVILLE
IRVINGTON
FLEETS BAY
NANDUA CREEK
PUNGOTEAGUE
WILTON
DELTAVILLE
JAMESVILLE
WARE NECK
MATHEWS
FRANKTOWN
ACHILLES
NEW POINT COMFORT
CAPE CHARLES
CHERITON
NORGE
YORKTOWN
POQUOSON WEST
POQUOSON EAST
ELLIOTTS CREEK
TOWNSEND
HAMPTON
NEWPORT NEWS SOUTH
N
0
20
KILOMETER
37° 00'
ATLANTIC OCEAN

Figure 8. Locations of topographic quadrangles in Virginia where SAV was observed and mapped in 1978.

TABLE 2. TOTAL AREAS OF SAV BY TOPOGRAPHIC QUADRANGLES FOR 1971, 1974, 1978

Quadrangle	Area (m²) by Year 1971	 1974	 1978
Hampton	2,958,100	3,064,600	2,182,500
Poquoson East	9,456,000	4,355,900	5,166,300
Poquoson West	4,892,900*	3,681,700*	2,104,400
Yorktown	*combined with Poquoson West		19,200
Clay Bank	1,134,100	120,800	0
Achilles	7,450,900	7,417,200	8,152,700
New Point Comfort	7,254,200	9,662,600	10,688,900
Ware Neck	1,535,600	1,890,000	2,560,000
Mathews	3,401,100	608,900	638,800
Wilton	2,960,700	79,000	104,300
Deltaville	5,432,900	230,000	594,300
Irvington	1,133,300	0	53,100
Fleets Bay	- -	1,975,600	1,332,300
Reedville	- -	- -	2,304,000
Elliotts Creek	- -	- -	579,400
Townsend	- -	- -	427,000
Cape Charles	- -	- -	3,214,200
Cheriton	- -	- -	852,000
Franktown	- -	- -	5,045,000
Jamesville	- -	- -	3,986,900
Nandua Creek	- -	- -	1,848,600
Pungoteague	- -	- -	4,016,300
Tangier Island	- -	- -	4,050,600
Chesconessex	- -	- -	4,825,400
Parksley	- -	- -	803,500
Ewell	- -	- -	14,479,000
Great Fox Island	- -	- -	3,979,000
Mathias Point	- -	- -	201,900
Dahlgren	- -	- -	83,200
Colonial Beach South	- -	- -	619,500
Norge	- -	- -	464,766

Note: -- indicates the area within Quadrangle was not mapped.

similar to the 1978 mapping, the distribution of SAV in 1971 and 1974 are presented for comparison.

Imagery was obtained from a series of mapping overflights that were made along the vegetated portions of Virginia's shoreline during midsummer (July or August) and early winter (November or December). All outlines and densities of SAV noted on the topographic quadrangles reflect maximum plant coverage which occurred normally on the summer imagery. Comparisons between the summer and winter imagery are discussed later.

Lower James River (Newport News South, Hampton quadrangles)

The Lower James River contained only a small area of SAV, primarily along the north shore of Hampton Roads. These areas were dominated by *Zostera* and are similar in coverage to those observed in 1971 and 1974. However, the density was much less than that found in the previous two surveys. The remainder of the lower James River was virtually devoid of any SAV. Presumably, this is due to the high turbidity levels found in that region.

James River to the York River (Hampton, Poquoson East and Poquoson West quadrangles)

This region contained significant concentrations of *Zostera* and *Ruppia* in both the Back and Poquoson Rivers and adjacent to Plum Tree Island. Back River had moderate to dense beds behind Northend Point. There were also moderately dense beds adjacent to Plum Tree Island at the mouth of the river. The reduction of SAV in the Northwest Branch of Back River accounted for most of the areal decrease reflected in Table 2. The upstream portions of the River were virtually devoid of SAV. Most probably a combination of high turbidity and a very shoal, silty littoral zone prevents their establishment.

The area adjacent to Plum Tree Island on the Poquoson East quadrangle contained moderate to dense beds of *Zostera* and *Ruppia*. Combined with the SAV beds found on the Poquoson Flats, this region has some of the largest grass areas in the lower Bay. Based on the areal computation for 1978, 1974 and 1971, there was however less grass in 1978 than observed in 1971 and 1974 (Table 2).

The Poquoson River and Crab Neck Areas contained sparse to moderately dense beds of *Zostera* and *Ruppia*, but compared with SAV areas denoted in 1971 and 1974 there had been a reduction in some areas off both Fish Neck and Crab Neck, adjacent to the Goodwin Islands and in the Thorofare. As with Back River, the upstream portions of the Poquoson River were devoid of SAV.

York River (Poquoson West, Achilles, Clay Bank and Yorktown quadrangles)

The distribution of SAV in the York River, an area where SAV has been intensively studied in previous years (March, 1970, 1973, 1976; Orth, 1971 1973, 1975, a,b, 1977 a,b; Orth and Gordon, 1975), was significantly different from that observed in 1971 and 1974. In 1971 extensive beds of Zostera and Ruppia were present on the south shore of the river from the Goodwin Islands to Yorktown. On the north shore, SAV beds were found from the Guinea Marshes as far upriver as Clay Bank, 30 km from the mouth of the York River. By 1974, only small scattered beds were evident on the south shore, while on the north shore, significant reductions in SAV density were observed from the Guinea Marshes to Gloucester Point with almost complete loss from Gloucester Point to Clay Bank. At that time, only a few scattered beds were observed around the Mumfort Islands and Blundering Point. In 1978, no significant vegetation was observed from Gloucester Point to Clay Bank and vegetation was still sparse from Gloucester Point to the Guinea Marshes when compared with 1971 distributions. Vegetation along Goodwin Neck and Goodwin Islands also showed reductions from 1974 to 1978.

Mobjack Bay (Achilles, Ware Neck, Mathews and New Point Comfort quadrangles)

The Mobjack Bay contained significant stands of SAV along most of its shoreline and the lower portions of its four tributaries: the Severn, Ware, North and East Rivers. The heads of these rivers were generally devoid of any SAV. Three areas along this region were investigated with intensive transects: the mouth of Browns Bay, Ware Neck Point and the mouth of East River. They contained dense beds of Ruppia and Zostera at all locations. In addition, the surface information obtained from many other locations indicated that the beds of SAV mapped throughout this region are predominately a mixture of Zostera and Ruppia. Interestingly, the Mobjack Bay area reflects the least alterations with respect to the distribution of SAV, of any other area observed in the lower Bay. Beds of SAV have maintained somewhat similar distributional limits since 1971.

Horn Harbor Area (New Point Comfort and Mathews quadrangles)

This area, extending from New Point Comfort north to the Milford Haven area, had moderate to dense beds adjacent to Horn Harbor and Potato Neck. Intensive transects conducted off Potato Neck revealed significant concentrations of Ruppia and Zostera. As in the Mobjack Bay, the distribution of SAV in this area has remained relatively stable since 1971.

Piankatank River Area (Mathews, Deltaville and Wilton quadrangles)

Very little SAV was observed in 1978 in the lower Piankatank River and Milford Haven area. Patchy SAV was observed adjacent to Gwynn Island, Stone Point Neck and at the mouths of Healy and Cobbs Creek. These areas had abundant grass in 1971 but had declined to very low levels by 1974. Much of the SAV observed in 1974 around Milford Haven and Stingray Point was gone in 1978. Zostera and Ruppia dominate the grass beds observed in this region. The head of the Piankatank contained small amounts of several oligohaline species (Nitella, Ceratophyllum, etc.) which could not be adequately observed from the air and therefore were not mapped onto the topographic quadrangles.

Rappahannock River (Deltaville, Wilton, Irvington, Urbanna quadrangles)

There were virtually no significant SAV beds in the lower Rappahannock River in 1978. Only very sparse beds were found on the north shore from Windmill Point to Towles Point. In 1971 there were extensive beds of *Zostera* and *Ruppia* on both shores of this river which had declined to very low levels by 1974.

Fleets Bay to Potomac River (Fleets Bay and Reedville quadrangles)

Sparse to moderately dense beds of SAV were found along this entire area. Most beds were small and very sparse and confined to the lower portions of the creeks and the Bay proper. The Fleets Bay area contained much more grass in 1974, but it was the only area in this region that was surveyed at that time. Many of the beds observed then declined in area or decreased in density by 1978. No SAV were observed within the lower portion of the Potomac River.

Northampton County (Townsend, Elliotts Creek, Cape Charles, Cheriton, Franktown and Jamesville quadrangles)

SAV were observed along most of the Bayside shoreline of this eastern shore county from Old Plantation Creek north to Occohannock Creek. The presence of SAV was generally associated with offshore bar formations, such that the areas with the most well defined and protective bars had the densest beds of SAV.

For much of this region the SAV consisted of large areas of quite sparse coverage. Vegetation in these sparse areas consisted primarily of *Zostera*. However, in two sections, dense beds of SAV were observed. The first area was adjacent to Cape Charles where moderate to dense beds were found adjacent to Savage Neck and the town of Cape Charles. These beds consisted of a mixture of *Zostera* and *Ruppia*. The second area was at the mouth of Hungar's and Mattawoman Creeks. Here exists a large bed along the south end of Church Neck off Vaucluse Shores that has been intensively studied by this and other projects. It has formed to the east of a large offshore bar and represented one of the heaviest concentrations of SAV along Virginia's eastern Bay shore. The vegetation is primarily *Zostera* and *Ruppia*.

The large tidal creeks which are found in this region contain vegetation only in their most downstream sections. Here *Ruppia* predominates with lesser amounts of *Zostera* scattered throughout. As with Hungars Creek, many of these beds have formed on old oyster bars which have not been maintained since the infestation of oyster pathogens in the 1950's.

Accomack County (Jamesville, Nandua Creek, Pungoteague, Chesconessex, Parksley, Great Fox Island, Ewell, Tangier Island quadrangles)

Large areas of relatively sparse SAV were observed along much of the Bayside shoreline of this county from Occohannock Creek north to Beasley Bay just south of Saxis. Most of these beds of SAV were vegetated with

Zostera and Ruppia. They were adjacent to the large brackish marshes found between the numerous tidal creeks. All SAV were observed within the lower portions of these creeks.

One of the densest concentrations of Zostera and Ruppia in the lower Chesapeake Bay occurred in the area to the east of Tangier Island and Smith Island. The very large, shoal area found here provides a very suitable habitat for SAV growth. The other Bay islands, especially the Fox Islands were also observed to have significant beds of SAV.

In summary, the distribution of SAV in the mesohaline and polyhaline regions of the lower Chesapeake Bay in 1978 was limited to the mouths of the major rivers and the east and west shorelines of the Bay. This is in contrast to 1971 when both the York and Rappahannock Rivers had extensive beds of SAV extending 20-40 km upstream of their mouths. Although the James River has not in recent history had extensive beds of SAV, those that did occur in 1971 had declined significantly by 1978. In addition the Potomac River, which was not formally studied in 1971 or 1974, is shown through historical photographs to have had significant beds of SAV in 1971 as far upstream as the mouth of the Coan River.

By comparing historical information, historical photography and anecdotal information, it has become apparent that since 1971 there has been a significant decline in total area vegetated with SAV. From 1971 to 1974, it appears that the submerged grasses (dominated by Zostera and Ruppia) had moved out of the rivers and decreased in abundance along the northern portions of Virginia's Chesapeake Bay shoreline (Figure 9). This dramatic decline from 1971 to 1974 has continued between 1974 and 1978. In addition, Dr. Richard Anderson (personal communications) of the American University reports finding little Zostera in Maryland waters in 1978.

This decline in distribution and abundance of SAV leaves Virginia with only a few areas of large, dense beds of submerged vegetation. These include: 1. along the western shore of the Bay between Back River and the York River, 2. the shoreline of Mobjack Bay, 3. shoal areas east of Tangier Island and other Bay islands, and 4. large beds formed behind protective sandbars along the Bay's eastern shore.

DISTRIBUTION OF SAV IN SELECTED OLIGOHALINE AND FRESHWATER AREAS

Observations made during the June, 1978, preliminary overflights of Virginia's tidal shoreline indicated an apparent lack of submerged vegetation within the oligohaline and freshwater portions of the major river systems. These include the Potomac, Rappahannock, Piankatank, York (including the Mattaponi and Pamunkey), and James Rivers as well as their major tributaries. The only areas where aerial reconnaissance revealed any SAV beds were: from Mattox Creek to Mathias Neck Point along the Potomac River, and along the Chickahominy River, a tributary of the James.

These two areas were thus selected for aerial mapping. The observed SAV beds along with the species information are included in Appendix B on the

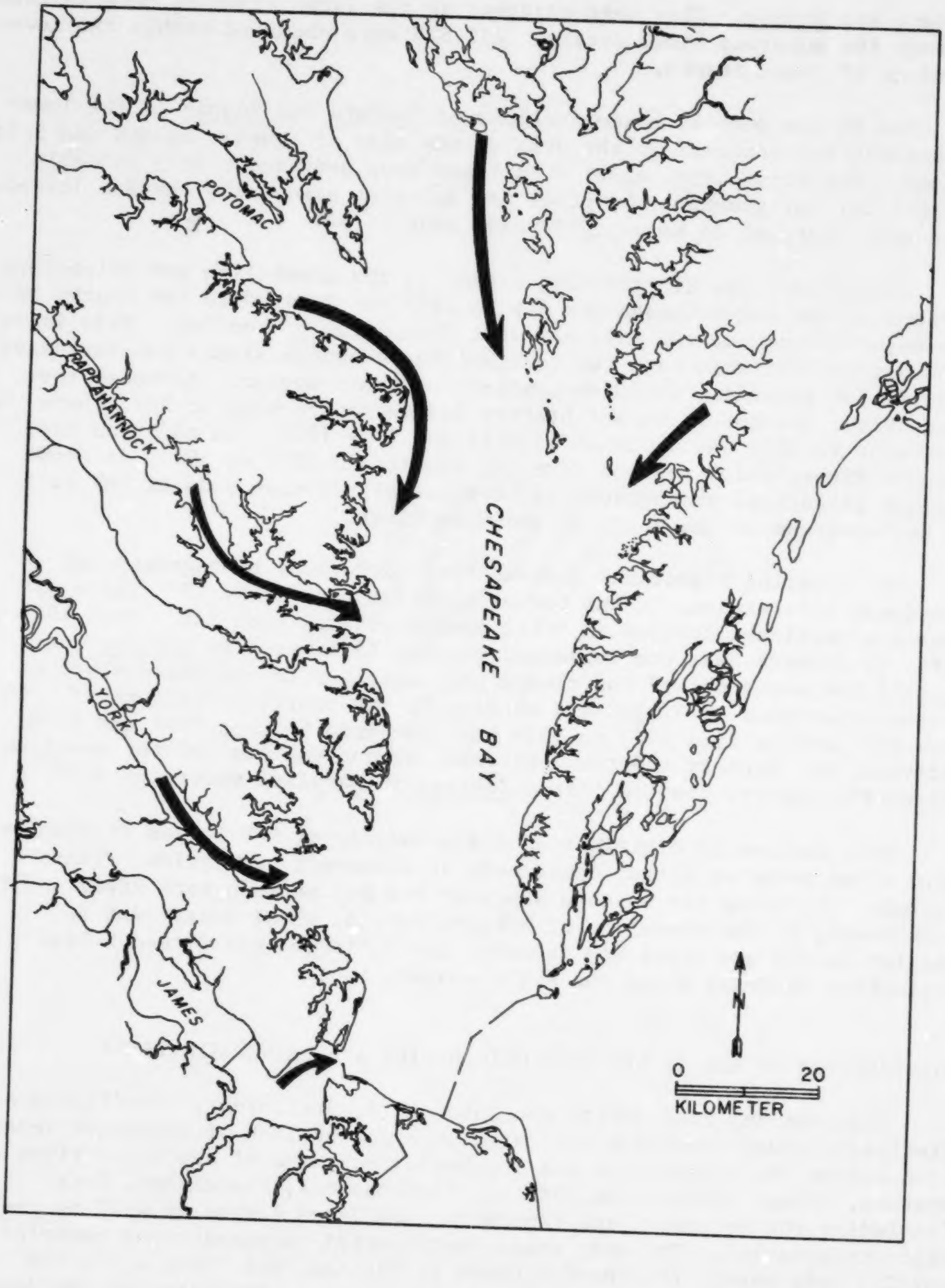

POTOMAC
RAPPAHANNOCK
YORK
JAMES
CHESAPEAKE
BAY
N
0
20
KILOMETER

Figure 9. Direction of recent changes in the distribution of Zostera dominated SAV beds.

Norge, Mathias Point, Dahlgren and Colonial Beach North Topographic sheets. More complete surface information obtained for these two areas is provided in Appendix C including species present, relative abundance and general observations. Sampling locations are illustrated in Figure 4.

Potomac River (Mathias Point, Dahlgren, Colonial Beach quadrangles)

The submerged aquatic vegetation found in the region between Mattox Creek and Mathias Neck Point consists primarily of intermittent beds fringing along the shorelines of the major creeks (<2 m depth at MLW). The most common species appears to be *Zannichellia palustris* which is found in numerous small (<5 m wide) patches along the creek shoreline. Other species including *Potomogeton crispus*, *Potomogeton perfoliatus*, *Vallisneria americana* dominate in much larger beds (5-20 m wide); *Zannichellia* is also present but only as an occasional species. It is these larger beds that are evident from the air. Salinities in this region vary considerably but are usually in the range of 5-10 ppt (Lear, unpublished data; Lippson et al., 1979).

Myriophyllum spicatum is a pest species which was common throughout this region from 1959 to the early 1970's (Beaven, 1960; Haven, 1961; Steenis, 1970). Moore (personal observation) reported dense stands of milfoil completely across the portions of Mattox Creek in the summer of 1975. During the summer of 1978, however, *Myriophyllum* was virtually absent from the major tidal creeks between the Yeocomico River and Upper Machodoc Creek, along the Virginia side of the Potomac. Scattered plants were observed at the head of Lower Machodoc Creek. Dense stands were observed only across the most upstream marsh channels of Rosier Creek. In both cases the *Myriophyllum* was mixed with *Zannichellia* in locations where it did not form extremely dense mats. There was no *Myriophyllum* found at all in Mattox Creek, while the Yeocomico River, which was reported to have had dense stands of milfoil in 1974 (Mercer, personal observation), was found to be devoid of all submerged aquatic vegetation. Also, no submerged aquatics were found in Bonum, Jackson, and Gardner Creeks located immediately north of the Yeocomico River.

Chickahominy River (Norge quadrangle)

The Chickahominy River, a major tributary of the James River, is the second low salinity area where submerged aquatics were observed from the air. For this study only the submerged aquatics occurring on the Norge topographic sheet have been mapped although they do occur throughout the river system. More complete surface information is provided in Appendix C and sampling locations are illustrated in Figure 4. The Chickahominy River is primarily an oligohaline to freshwater, tidal river (mean tidal range of 0.7 m, NOS Tide Table) in which salinities rarely exceed 0.5°/oo (VIMS, Data Base). Water samples taken from Shipyard, Yarmouth and Gordon's Creeks on August 24, 1978, during high tide, revealed salinities of between 0.15 and 0.45°/oo. Like many of the rivers and creeks in the vicinity, the Chickahominy is a drowned, Pleistocene river valley that has been filled to about present sea level with layers of sands, clays, and muck (organic matter). It is a relatively undisturbed, natural area characterized by over

2,500 hectares of tidal marsh. Over thirty species of emergent vegetation have been recorded for this area (Moore, 1979) with the most dominant being *Peltandra virginica*, *Pontederia cordata*, *Zizania aquatica*, *Nuphar luteum* and *Bidens* sp. Extensive areas of swamp forest dominated by *Taxodium distichum* are also found in bands between the open marsh and the surrounding hardwood-pine forest.

The Chickahominy region is a confirmed nursery and spawning area for many species of anadromous fishes, particularly those of the genus *Alosa* (Van Engle and Joseph, 1968). It also supports many resident species such as *Micropterus salmoides* (large mouth black bass) (Raney, 1950). In addition, it is a valuable habitat for many species of waterfowl; particularly during the winter months when the area is inhabited by many species of migrating ducks and geese.

The submerged aquatics found here occur primarily as narrow (<2 meters) fringing beds located along the edge of the marsh channels at water depths of less than 1 meter. Dominant species include *Ceratophyllum demersum* and *Najas minor* but commonly associated species are *Nitella* sp., *Elodea canadensis*, *Najas guadalupensis*, with *Najas flexilis* recorded at one location. In many cases, because of the presence of the emergent *Peltandra*, *Pontederia* and especially *Nuphar* species, the submerged aquatics are not readily seen from the air. *Ceratophyllum* was commonly observed from the surface growing under areas of *Nuphar*. This combined with heavy encrustation by epiphytes and silts and the likewise dark background of the bottom makes it difficult to distinguish the *Ceratophyllum* from an airplane even at low tide.

In addition to the fringing and embayed SAV beds found along the Chickahominy River, numerous small pockets of submerged vegetation were discovered at the most upstream portions of the marsh guts. Not every gut contained vegetation, however, those that did generally contained both *Najas minor* and *Ceratophyllum demersum* and in the deepest sections *Vallisneria americana*. In most cases these small pockets of submerged grasses were not evident from the air.

It appears then, that from our experience in these two oligohaline and freshwater portion of Virginia's tidal rivers, aerial reconnaissance combined with aerial photography is useful in mapping the larger beds of SAV. However from altitudes (1500-3700 meters) suitable for mapping large areas of shoreline SAV, those located in the many smaller fringing beds, as well as small pocket areas, are not readily detectable.

COMPARISON OF IMAGERY OBTAINED ON SUMMER AND WINTER OVERFLIGHTS

Significant reductions in the amount of SAV were evident on the winter imagery when compared to the summer imagery and confirmed with surface ground truth information. This reduction was due to the normal die-back of the submerged vegetation and, although not uniform, reductions were observed in nearly every SAV bed. For comparison, two areas (Back River and Tangier Island) were selected as representative of seasonal changes observed in the imagery throughout the lower Bay. These areas reflect the range of reduction that might be expected at any one site for 1978. From year to year, however, this change in coverage will vary for each individual bed. During some winters virtually no SAV can be observed from the air (Orth, 1976).

Figure 10 presents the SAV bed outlines and the appropriate percent cover estimates for the areas surrounding Tangier Island during July and December 1978 (Tangier Island quadrangle). Tangier Island is one of the areas that experienced an exceptional reduction in SAV as evidenced by the aerial imagery. This amounted to nearly an 83% decrease in coverage (Table 3).

TABLE 3. SUMMER-WINTER COMPARISONS OF AREAL COVERAGE BY SAV AT TANGIER ISLAND AND BACK RIVER

		Area (meter^2)				
Date	Location	<10%	10-40%	40-70%	70-100%	Total
7-7-78	Tangier Island	124,500	374,820	1,763,538	18,612	2,281,470
12-6-78	Tangier Island	33,522	139,908	225,22	0	398,652
6-29-78	Back River	212,388	159,180	262,194	1,456,410	2,090,172
12-7-78	Back River	0	0	841,362	420,480	1,261,842

Back River (see Hampton quadrangle) experienced somewhat less of a dieback from summer to winter. Figure 11 presents the SAV bed outlines and percent cover zones for an area at the mouth of Back River. This seasonal change amounted to a 40% reduction in observable SAV coverage (Table 3).

In both of the areas described above (Tangier Island and Back River), the beds of SAV are dominated by a mixture of both *Zostera* and *Ruppia*. Evidence from these as well as many other areas around the lower Bay indicate that both species decline in a similar fashion during the fall and winter. Figure 12 illustrates seasonal changes in both standing crop (biomass) and number of shoots of *Zostera* at Vaucluse Shores on the Bayside of Virginia's eastern shore. As evidenced from Figure 12, maximum standing crop occurs in the June-July period, with minimum coverage in the September-October period. *Zostera* has two growth phases, the strongest one occurring in the spring and a second, less intense one, in the fall after die-back in late summer. Though similar data are not available at present for *Ruppia*, personal observations at several sites in the lower Bay indicate that this species has a peak standing crop in August with minimum standing crop during the winter months. Therefore, attributing declines in coverage to one or the other of the species are probably not valid.

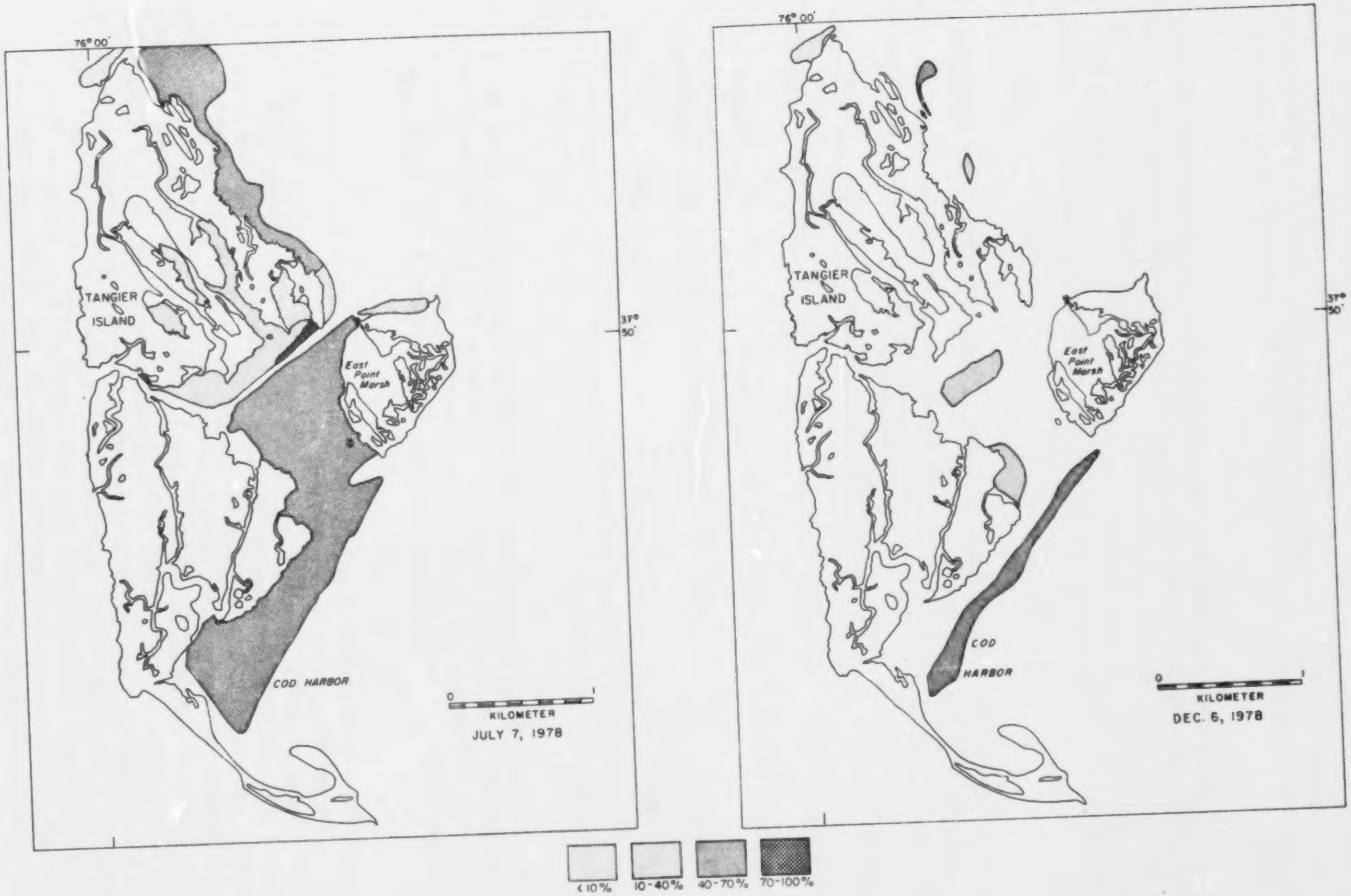

76°00'
37°
50'
TANGIER
ISLAND
East
Point
Marsh
COD HARBOR
0
1
KILOMETER
JULY 7, 1978
DEC. 6, 1978
<10%
10-40%
40-70%
70-100%

Figure 10. Distribution and abundance of SAV delineated from summer and winter photography at Tangier Island.

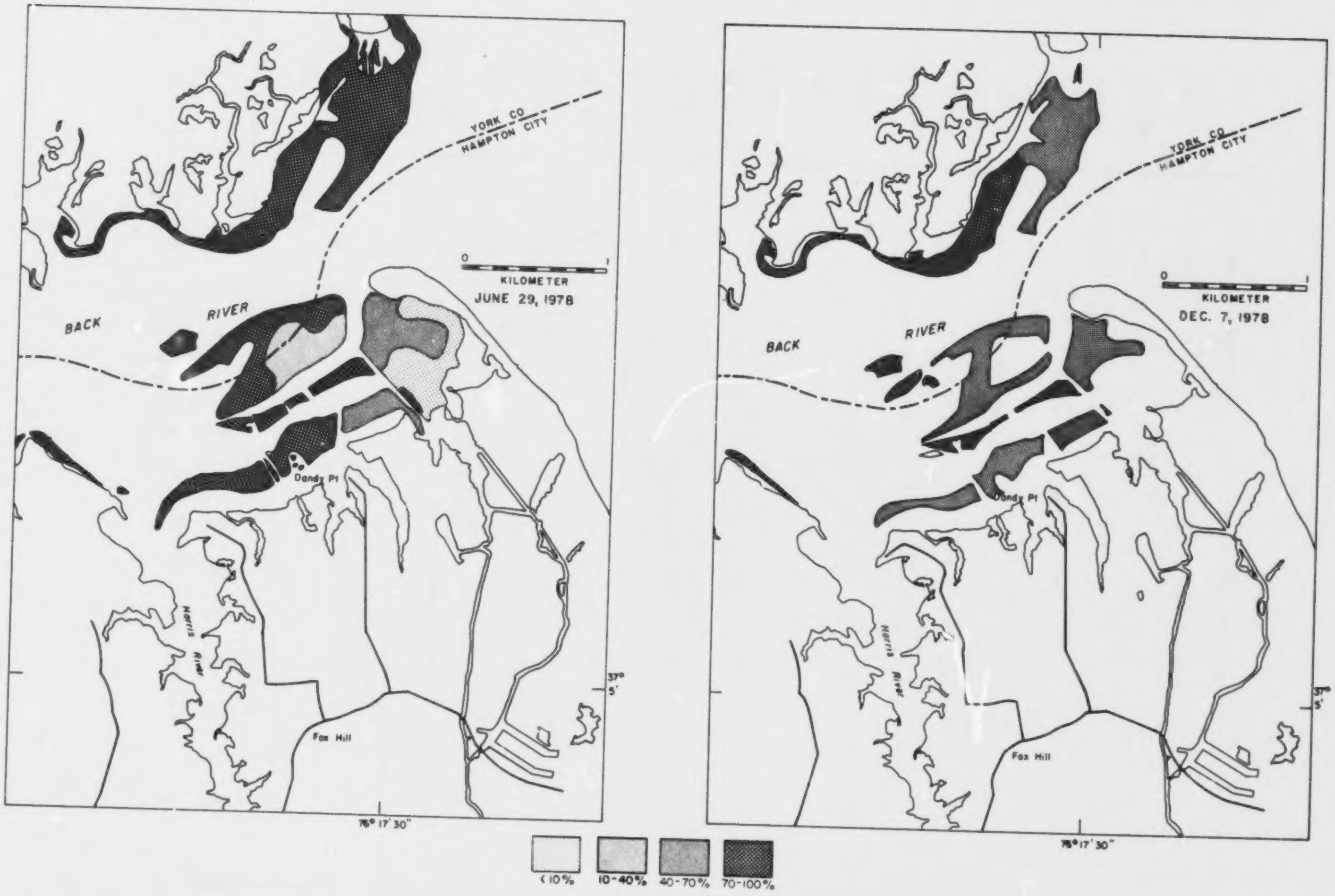

YORK CO
HAMPTON CITY
0
1
KILOMETER
JUNE 29, 1978
DEC. 7, 1978
BACK
RIVER
Dandy Pt
Harris River
Fox Hill
37°
5'
76° 17' 30"
<10%
10-40%
40-70%
70-100%

Figure 11. Distribution and abundance of SAV delineated from summer and winter aerial photography at Back River.

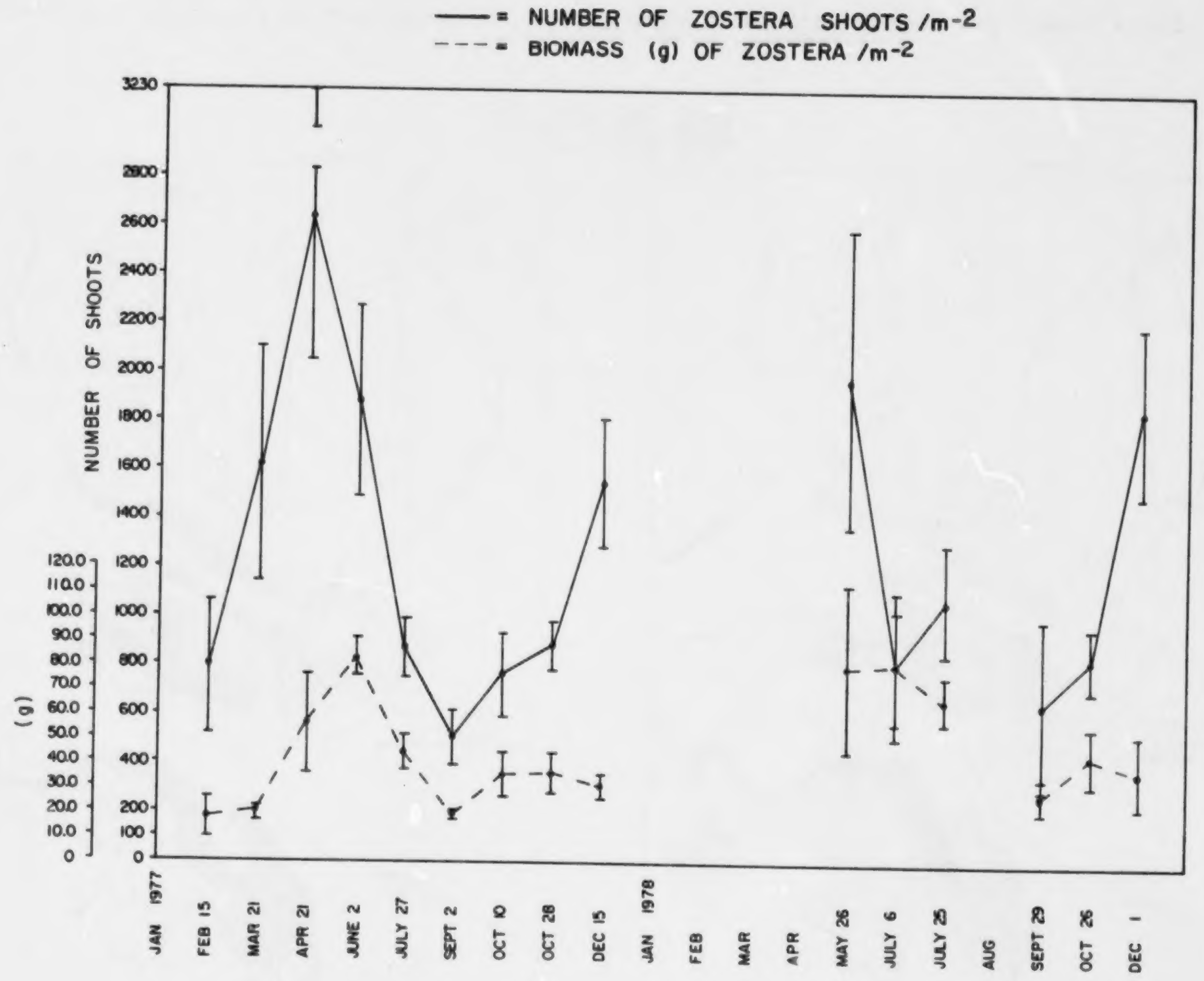


Figure 12. Seasonal changes in the number of shoots and biomass of *Zostera* at Vaucluse Shores, 1977-1978.

It was evident that the areas throughout the Bay which were observed to have the sparcest coverage during the summer (i.e. <40%) were not able to be observed during the winter. The reduction in standing copy of those sparce areas during the late summer - early fall period resulted in virtually no SAV on the imagery even though there may have been a minimal standing stock present. It is possible, though, that had the photography been flown at a much lower altitude some SAV would have been detected.

Those areas with the highest concentrations of SAV during the early summer had the best chance of being observed during the winter. For example, Tangier Island which contained a large proportion of very sparce (<10%) and sparce (10-40%) SAV areas, showed very little SAV during the winter. Back River, in contrast, contained a large proportion of very dense (70-100%) areas. These areas were still observed during the December overflight, although in generally a less dense status.

HISTORICAL DISTRIBUTION OF SAV

A review of the past photography for five of the six historical areas revealed significant alterations in the distribution and abundance of SAV. Only the eastern shore site did not show significant alterations. The earliest photographs obtained for each area are 1937 or 1938 and, thus presented is a 40 year period on which to base changes in SAV in the lower Bay. We attempted to secure photographs taken during the early summer period when the SAV would be at their maximum abundance. However in most cases, available photographs were for the late spring and fall periods and, therefore, may not reflect the maximum occurrence of SAV for that year. Photographs for years not presented here were carefully reviewed for SAV distribution, so as to present the most accurate picture of the changes of SAV beds.

All areas used in the historical analysis currently contain *Zostera*. It was noted that in the 1937 photographs there was less grass than in the 1950's and 1960's. This period of the 1930's coincided with the well-documented massive decline of *Zostera* on the East Coast of the U.S. and the west coast of Europe (Rasmussen 1973, 1977). During the early 1930's, eelgrass in many bays and rivers in coastal areas declined drastically. At first, this decline was thought to be caused by a parasite, *Labyrinthula* spp. (Renn, 1934, 1935). Later hypothesis suggested that environmental factors such as temperature may have been involved (Rasmussen, 1973). Whatever factor(s) caused this major decline, *Zostera* beds in the Chesapeake Bay were similarly impacted.

Parrott Islands (Table 4; Fig. 13)

In 1937, there were 1.89×10^6 m^2 of SAV adjacent to the Parrott Islands with the grass being sparce to moderate in all areas. By 1951, the SAV occupied area increased to 3.55×10^6 m^2 with 67% of that area having moderate to dense grass. SAV had expanded outward from land and less dense areas became more dense. In 1960, 3.53×10^6 m^2 were occupied by SAV with 70% being moderate to dense vegetation. However, by 1968,

TABLE 4. AREAS OF SAV AT HISTORICAL MAPPING SITES, 1937-1978

Parrott Islands

Date	Area m² <10%	10-40%	40-70%	70-100%	Total
1937	0	297,024	1,598,268	0	1,895,292
1951	394,797	778,146	1,222,410	1,158,384	3,553,737
1960	411,306	631,566	547,014	1,947,372	3,537,258
1968	92,064	1,354,110	1,205,628	124,374	2,776,176
1974	0	2922	7710	0	10,632
1978	0	22,872	0	0	22,872

Fleets Bay

Date	Area m² <10%	10-40%	40-70%	70-100%	Total
1937	0	1,385,424	548,076	744,864	2,678,364
1953	1,488,258	597,354	591,018	284,232	2,960,862
1961	1,572,612	1,330,140	1,643,892	884,280	5,430,924
1969	1,436,403	1,938,660	1,592,170	270,372	5,237,605
1974	105,714	1,624,884	1,325,040	0	3,055,638
1978	167,688	528,918	33,592	0	730,198

Mumfort Islands

Date	Area m² <10%	10-40%	40-70%	70-100%	Total
1937	0	495,060	397,368	23,832	916,260
1953	151,728	699,252	106,356	1,461,846	2,419,182
1960	0	258,210	1,880,238	0	2,138,448
1971	0	685,536	1,088,976	0	1,774,512
1974	0	127,488	23,826	0	151,314
1978	0	0	0	0	0

(continued)

TABLE 4 (continued)

Jenkins Neck

	Area m^2				
Date	<10%	10-40%	40-70%	70-100%	Total
1937	0	1,180,200	820,612	32,520	2,033,332
1953	426,480	647,112	717,180	1,811,832	3,602,604
1960	140,448	794,178	639,012	2,067,948	3,641,586
1971	0	278,586	2,350,380	33,792	2,662,758
1974	93,972	303,804	1,599,228	93,912	2,090,916
1978	132,714	299,760	671,616	162,408	1,266,498

East River

	Area m^2				
Date	<10%	10-40%	40-70%	70-100%	Total
1937	1,024,010	809,770	1,357,790	85,530	3,277,100
1953	591,840	1,158,490	1,394,740	1,742,050	4,887,120
1963	31,032	1,916,530	2,340,480	0	4,288,042
1971	0	2,007,460	2,253,080	96,620	4,307,160
1974	509,730	348,820	1,955,130	0	2,813,680
1978	47,860	515,000	1,864,850	0	2,427,710

Vaucluse Shores

	Area m^2				
Date	<10%	10-40%	40-70%	70-100%	Total
1938	0	1,120,284	1,451,392	1,480,128	4,051,804
1949	506,706	1,771,884	1,715,556	0	3,994,146
1955	1,938,258	0	528,996	1,238,124	3,705,378
1966	452,940	402,324	2,534,178	604,176	3,993,618
1972	286,554	364,764	2,515,740	391,770	3,558,828
1978	187,728	507,054	80,872	2,036,526	2,812,180

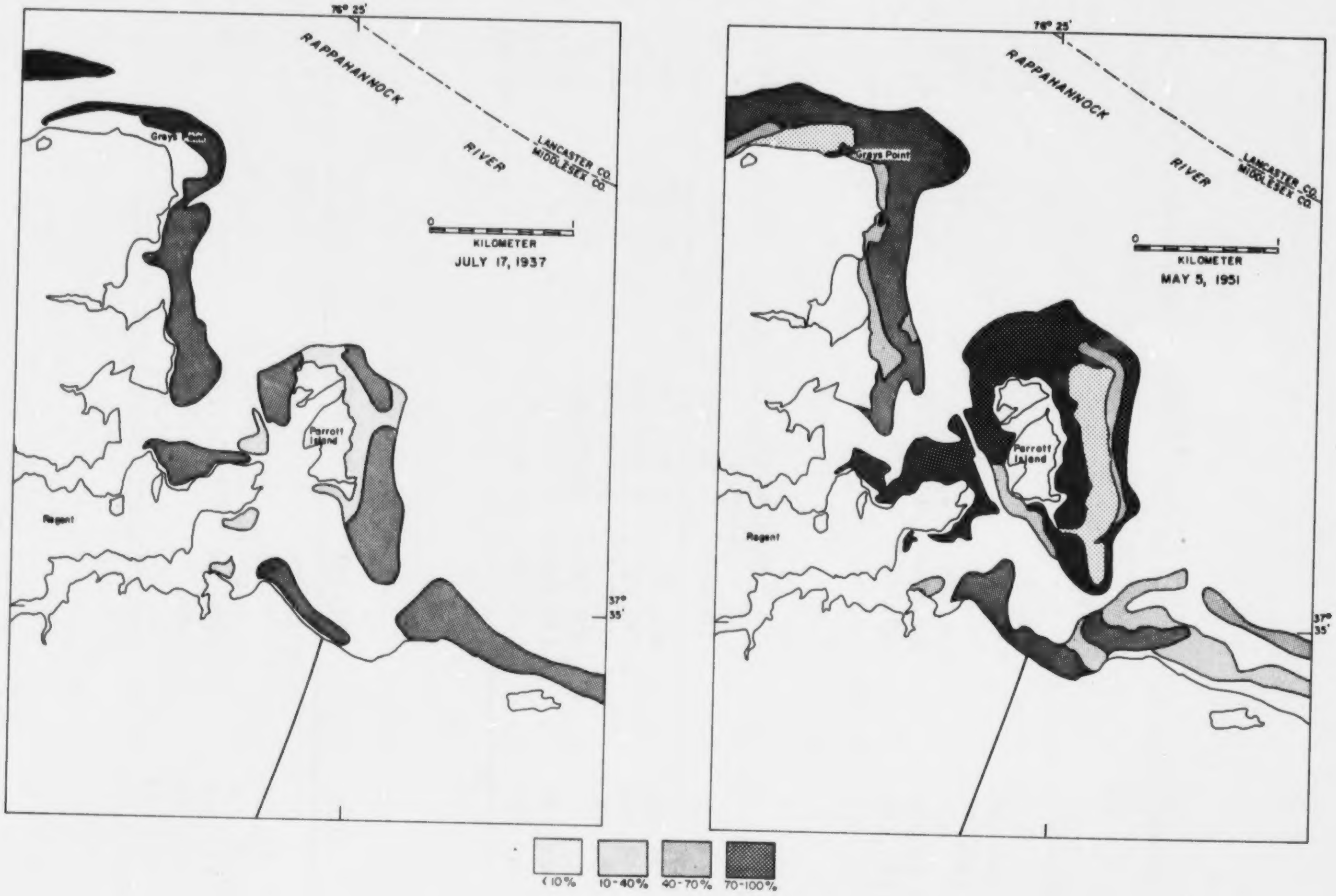

76° 25'
RAPPAHANNOCK
RIVER
LANCASTER CO.
MIDDLESEX CO.
0
1
KILOMETER
JULY 17, 1937
MAY 5, 1951
Grays Point
Parrott Island
Regent
37° 35'
<10%
10-40%
40-70%
70-100%

Figure 13. Changes in the distribution and abundance of SAV at Parrott Island, 1937-1978.

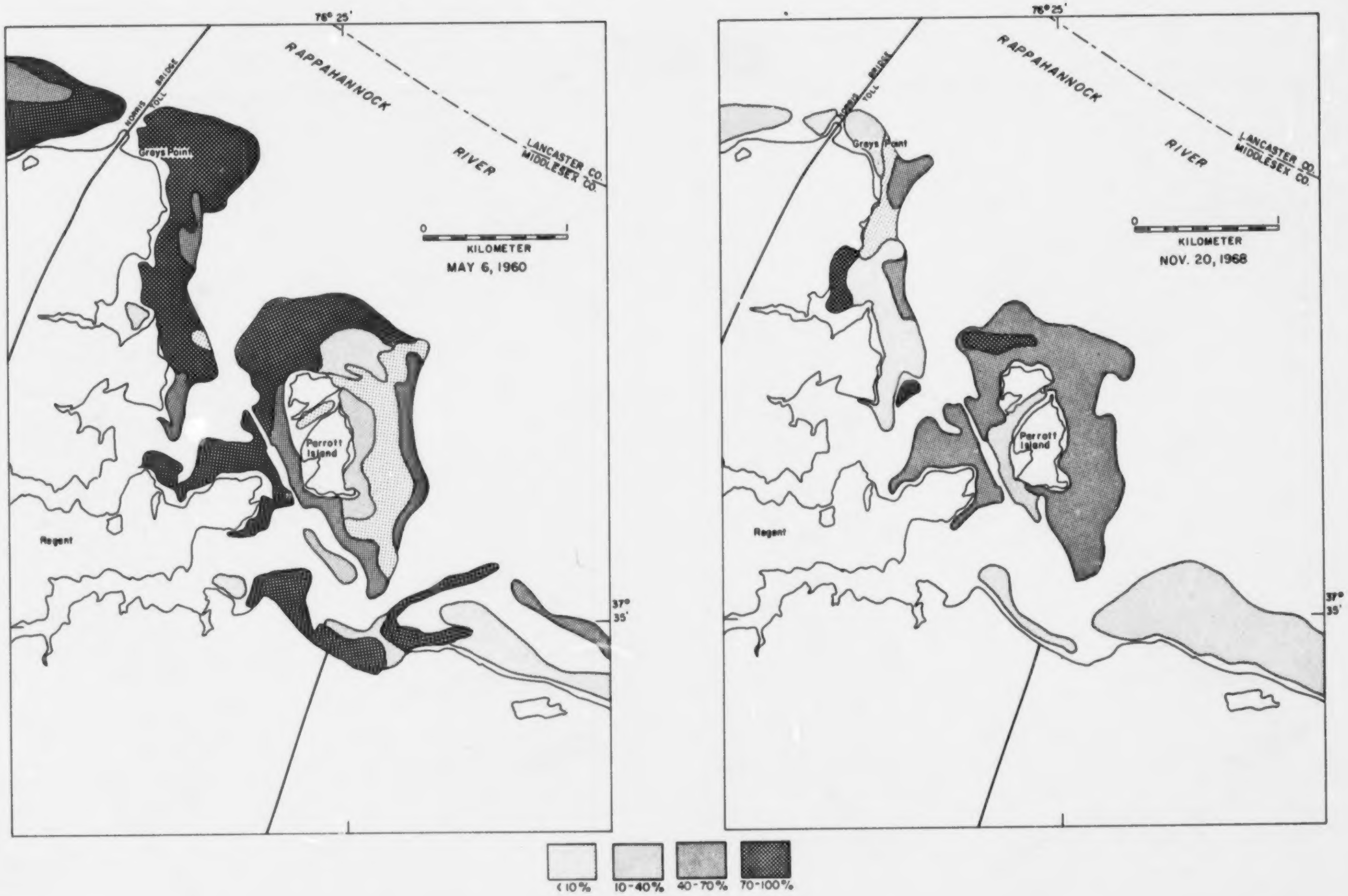

76° 25'
RAPPAHANNOCK
RIVER
LANCASTER CO.
MIDDLESEX CO.
NORRIS TOLL BRIDGE
Greys Point
0
1
KILOMETER
MAY 6, 1960
Parrott Island
Regent
37° 35'
NOV. 20, 1968
<10%
10-40%
40-70%
70-100%

Figure 13. (Continued)

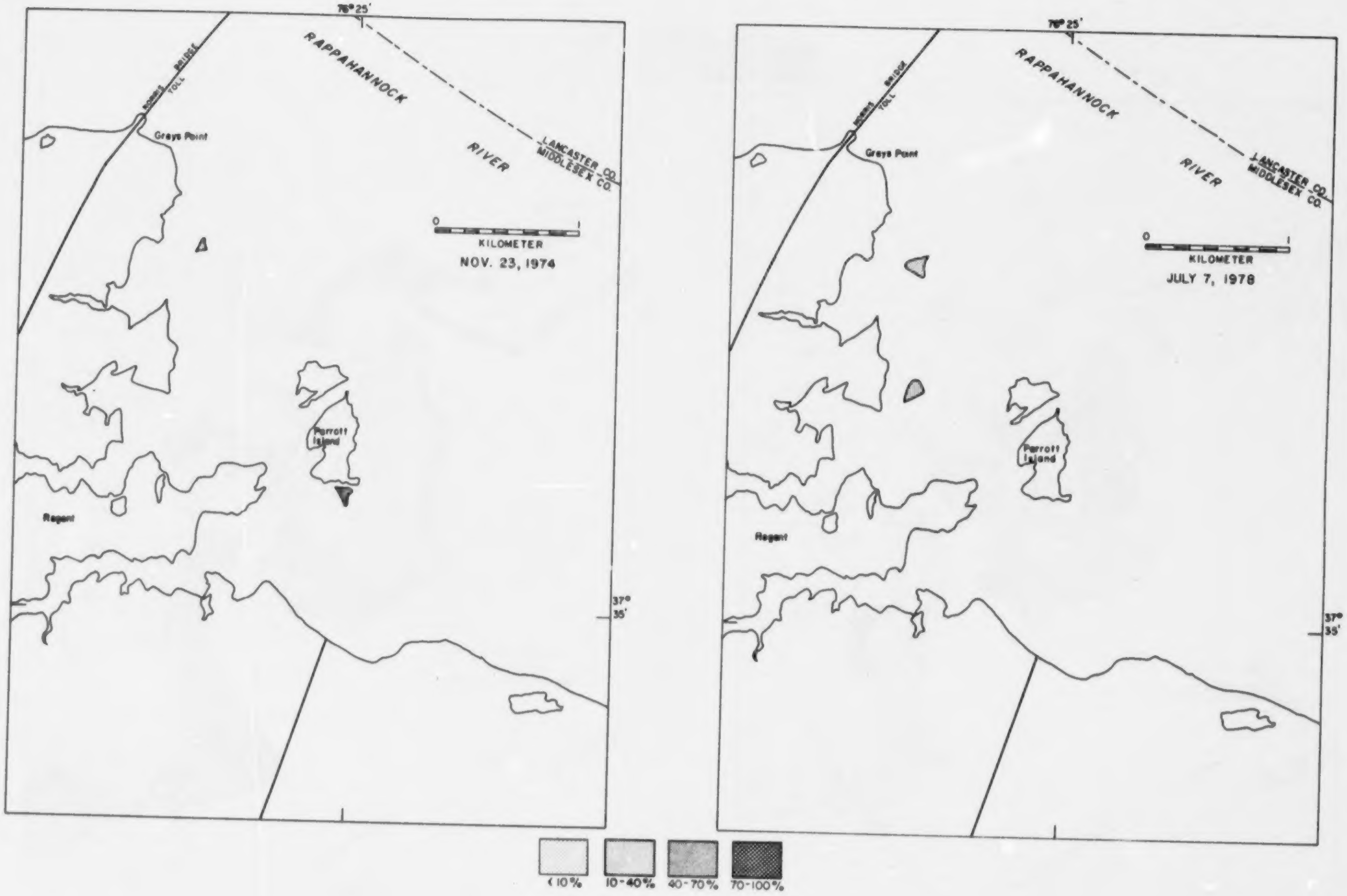

76° 25'
RAPPAHANNOCK
RIVER
LANCASTER CO.
MIDDLESEX CO.
NORRIS TOLL BRIDGE
Greys Point
0
1
KILOMETER
NOV. 23, 1974
Parrott Island
Regent
37° 35'
76° 25'
RAPPAHANNOCK
RIVER
LANCASTER CO.
MIDDLESEX CO.
NORRIS TOLL BRIDGE
Greys Point
0
1
KILOMETER
JULY 7, 1978
Parrott Island
Regent
37° 35'
<10%
10-40%
40-70%
70-100%

Figure 13. (Continued)

SAV area was reduced to 2.77×10^6 m^2 with 92% of that area in sparce to moderate densities. The SAV density data for 1968 was acquired in November and may not indicate an actual decline of SAV but rather a winter density minimum. It is assumed then that the difference in area described here between 1960 and 1968 may not be real but actually an artifact of the time the imagery was taken. In 1974 the changes were drastic; only 10,000 m^2 of SAV remained, a 99% reduction. Even though these data were derived from November photographs, an aerial reconnaissance of this river, and this area in particular in 1974 revealed no SAV even during the early summer months. The abundance of SAV has remained low in this area through 1978. Presently, SAV around Parrott Island is at the lowest density observed in the last 40 years.

Fleets Bay (Table 4; Fig. 14)

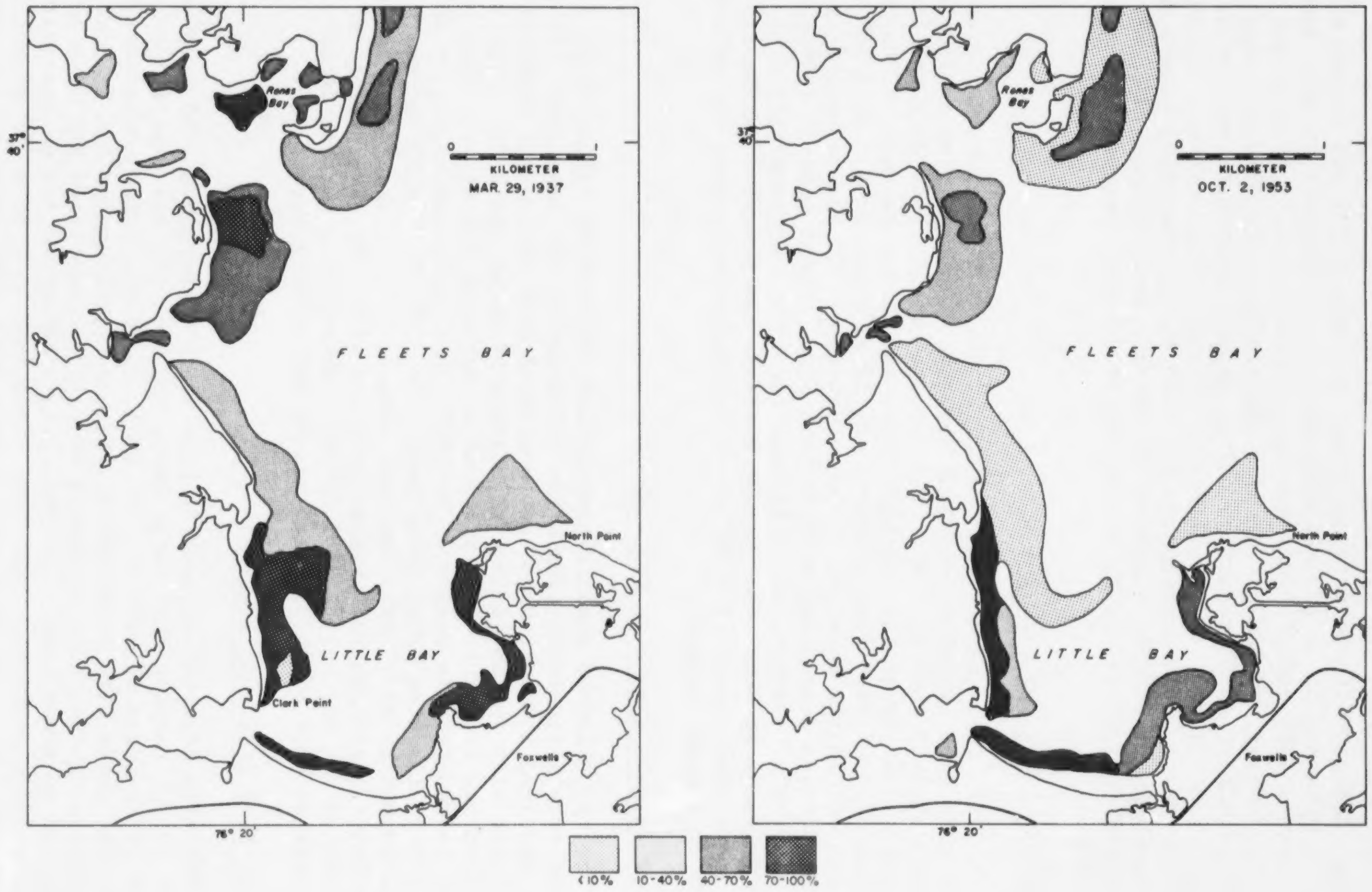
In 1937, there were 2.67×10^6 m^2 of SAV in the Fleets Bay area with 50% of this area having only sparce coverage. No significant changes occurred by 1953 when 2.96×10^6 m^2 were recorded. This data was from a fall period and densities for both years may be low because of low SAV standing crop at that time of year. By 1961, there were 5.43×10^6 m^2 of SAV with 46% in the moderate to dense category. It can be seen from Figure 14 that SAV was increasing Bayward from land. Total area in 1969 was 5.23×10^6 m^2. However, the fall data for 1974 indicated only 3.05×10^6 m^2, a decrease of 40%. The largest decrease has occurred during the last four years with only 0.73×10^6 m^2 of SAV being left, most in the very sparce to sparce category.

Mumfort Islands (Table 4; Fig. 15)

The SAV's in the shallow area around the Mumfort Islands have been studied more intensively than other SAV areas in the lower Bay. Most of these studies, however, have been concerned with the animal community associated with the SAV's (see references by Marsh and Orth). In 1937 this area had less than 0.91×10^6 m^2 of SAV with 70% of this area being sparce to moderate in density. By 1953, this increased to 2.41×10^6 m^2 with 60% of the area being dense beds. In 1960, 2.13×10^6 m^2 was estimated but by 1971, this had been reduced to 1.77×10^6 m^2. The greatest reduction of SAV occurred between 1971 and 1974. By 1974, the total area occupied by SAV was only 1.51×10^6 m^2. There was a further decline after this year so that by 1978, there was no SAV in this area.

Jenkins Neck (Table 4; Fig. 16)

The area adjacent to Jenkins Neck in 1937 contained 2.03×10^6 m^2 of SAV in 1937. Despite this large area, however, 98% was classified as sparce or moderate in density. By 1953, as in the other areas discussed above, the grass beds increased in size by expanding out and increasing in density. During this period, 3.60×10^6 m^2 contained SAV with 50% classified as dense beds. In 1960, 3.64×10^6 m^2 of SAV was estimated with 57% classified as dense. This area diminished to 2.66×10^6 m^2 by 1971 and declined to 2.19×10^6 m^2 by 1974 with further reductions in succeeding years. By 1978, there were only 1.26×10^6 m^2 of SAV remaining.



Rones Bay
37° 40'
0
1
KILOMETER
MAR. 29, 1937
FLEETS BAY
LITTLE BAY
Clark Point
North Point
Foxwells
76° 20'
Rones Bay
37° 40'
0
1
KILOMETER
OCT. 2, 1953
FLEETS BAY
LITTLE BAY
North Point
Foxwells
76° 20'
<10%
10-40%
40-70%
70-100%

Figure 14. Changes in the distribution and abundance of SAV at Fleets Bay, 1937-1978.

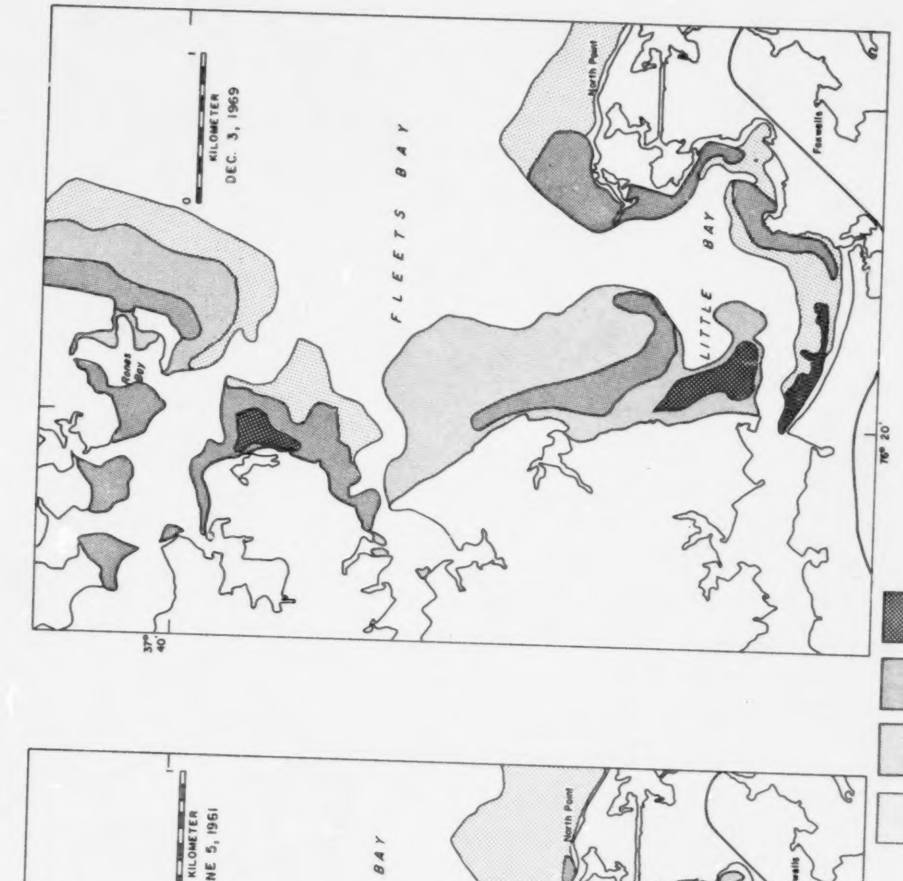

KILOMETER
JUNE 5, 1961
0
1
FLEETS BAY
LITTLE BAY
Rones Bay
North Point
Foxwells
37° 40'
76° 20'
KILOMETER
DEC. 3, 1969
0
1
FLEETS BAY
LITTLE BAY
Rones Bay
North Point
Foxwells
37° 40'
76° 20'
<10%
10-40%
40-70%
70-100%

Figure 14. (Continued)

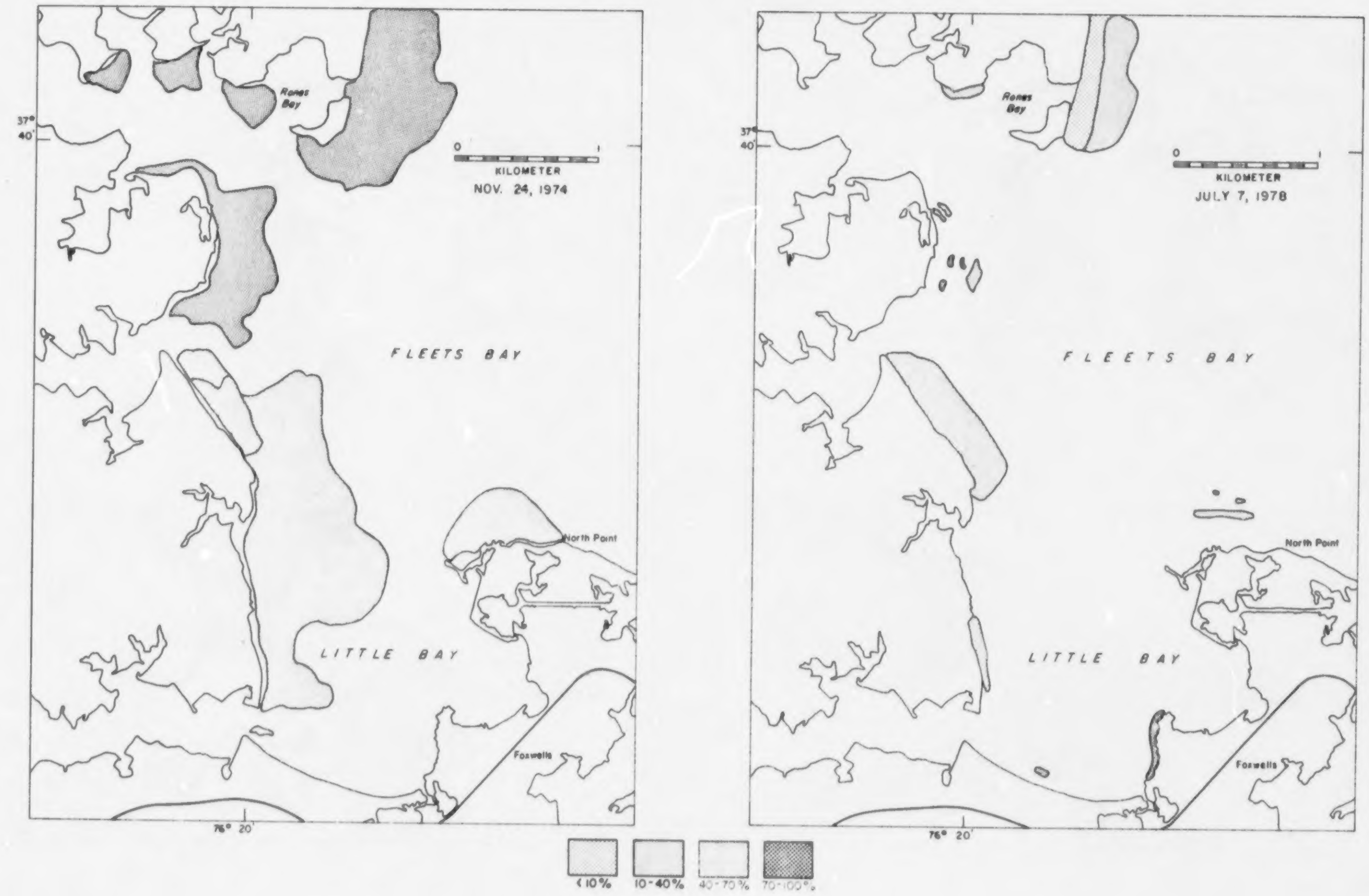

Rones Bay
37° 40'
0
1
KILOMETER
NOV. 24, 1974
FLEETS BAY
North Point
LITTLE BAY
Foxwells
76° 20'
Rones Bay
37° 40'
0
1
KILOMETER
JULY 7, 1978
FLEETS BAY
North Point
LITTLE BAY
Foxwells
76° 20'
<10%
10-40%
40-70%
70-100%

Figure 14. (Continued)

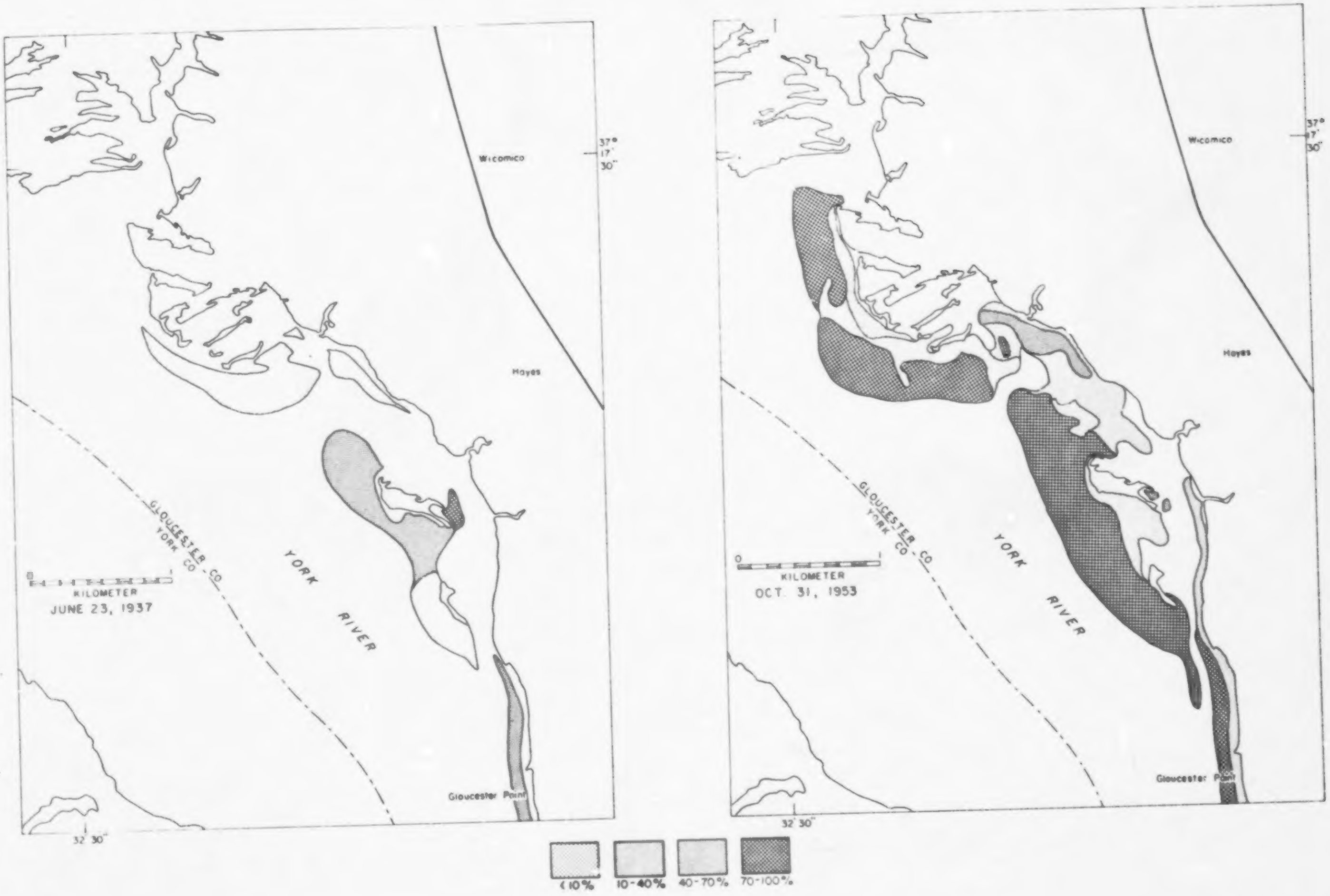

Wicomico
37°
17'
30"
Hayes
GLOUCESTER CO
YORK CO
YORK RIVER
0 1
KILOMETER
JUNE 23, 1937
OCT. 31, 1953
Gloucester Point
32' 30"
<10%
10-40%
40-70%
70-100%

Figure 15. Changes in the distribution and abundance of SAV at Mumfort Island, 1937-1978.

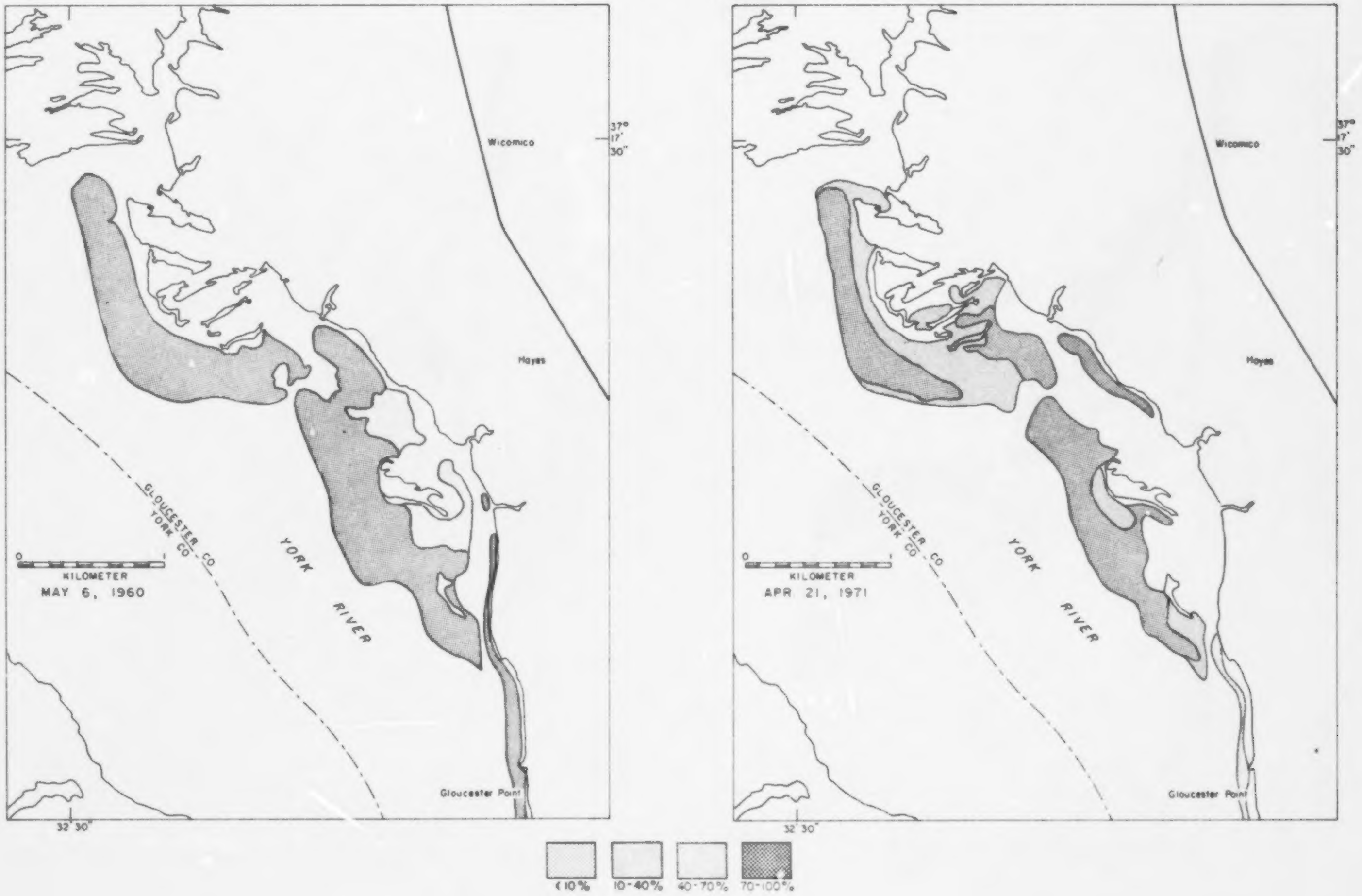

Wicomico
Hayes
37°
17'
30"
YORK RIVER
GLOUCESTER CO
YORK CO
0
1
KILOMETER
MAY 6, 1960
APR 21, 1971
Gloucester Point
32' 30"
<10%
10-40%
40-70%
70-100%

Figure 15. (Continued)

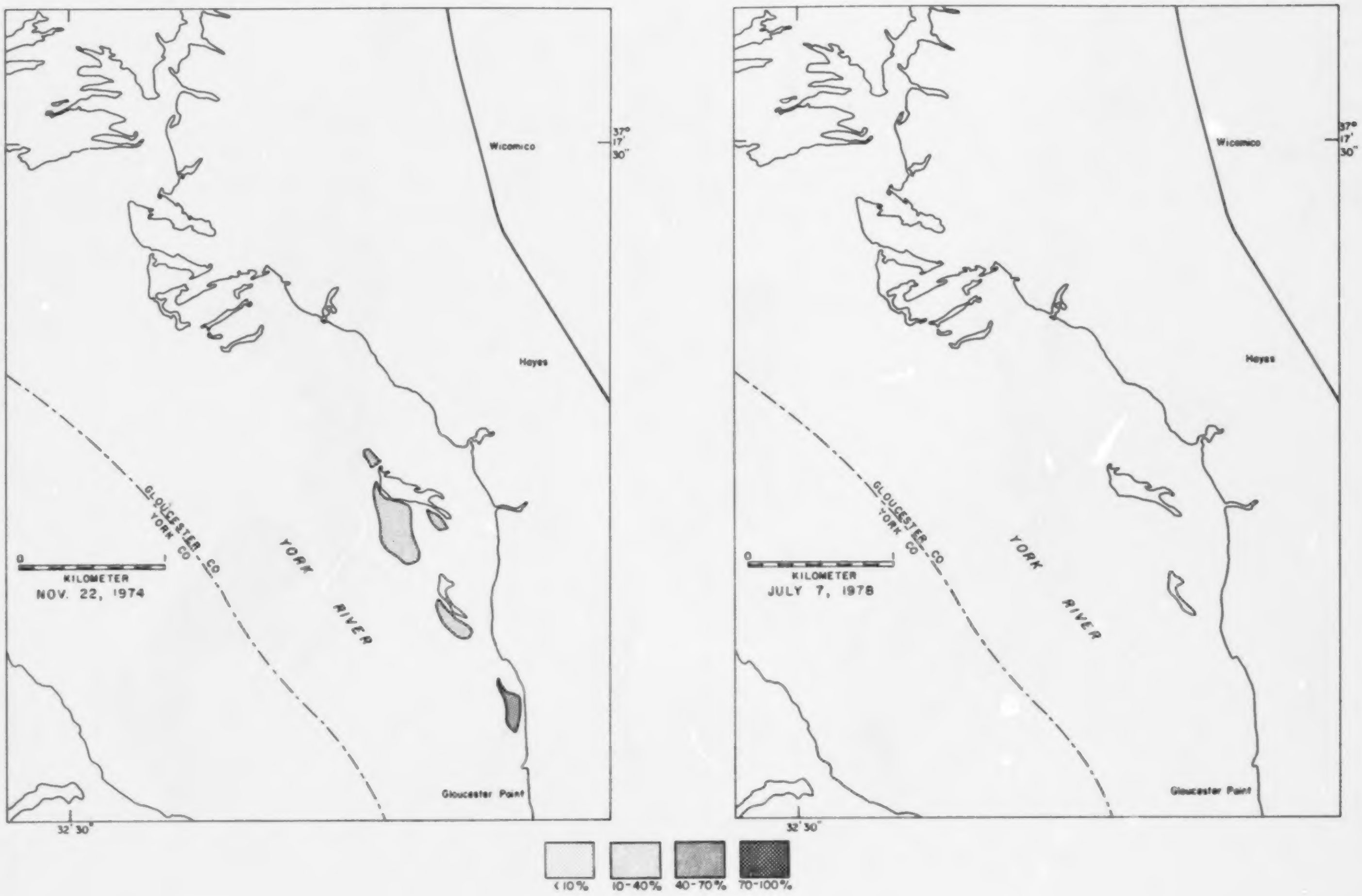

Wicomico
Hayes
Gloucester Point
37° 17' 30"
32' 30"
YORK RIVER
GLOUCESTER CO
YORK CO
0
1
KILOMETER
NOV. 22, 1974
JULY 7, 1978
< 10%
10-40%
40-70%
70-100%

Figure 15. (Continued)

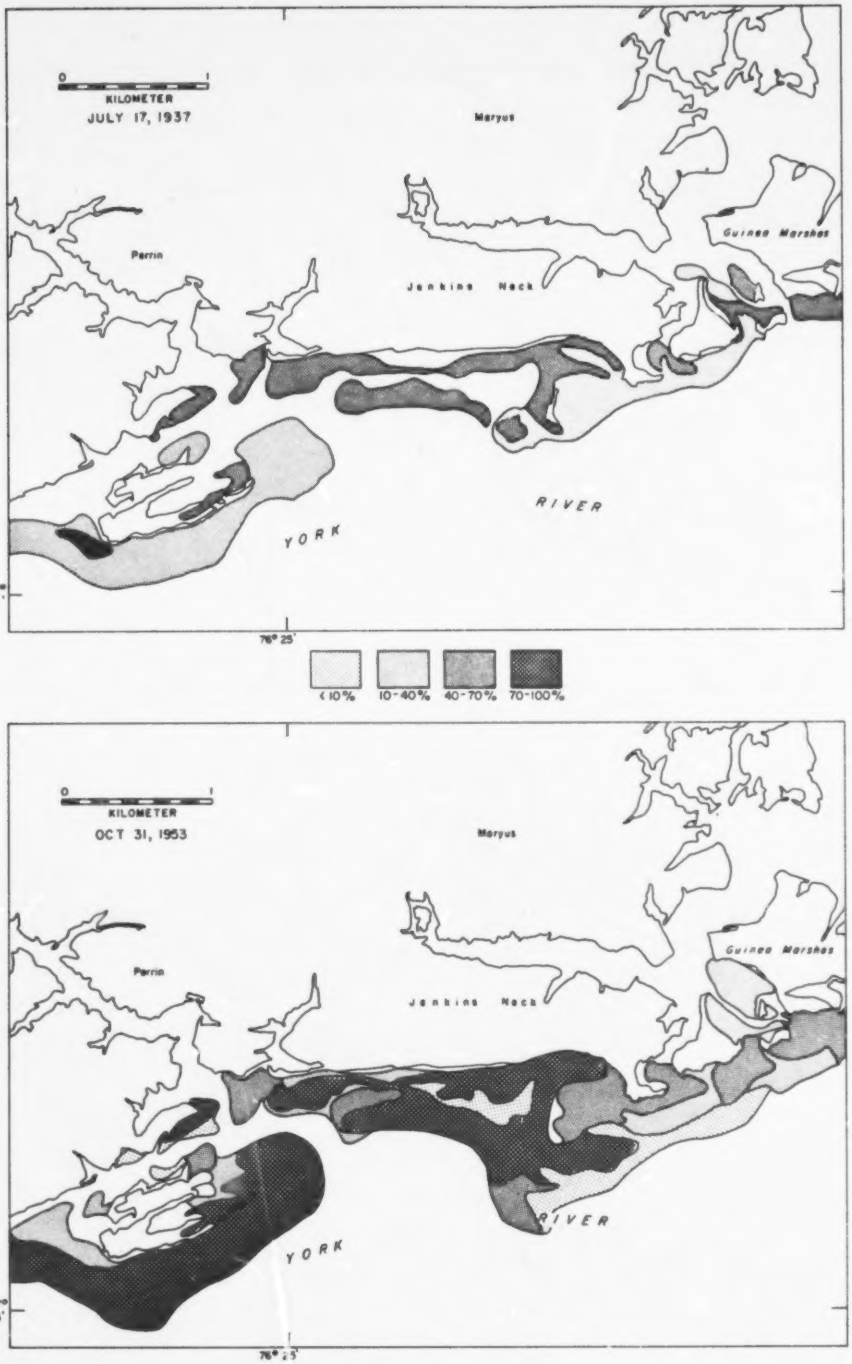

0
1
KILOMETER
JULY 17, 1937
Maryus
Perrin
Jenkins Neck
Guinea Marshes
RIVER
YORK
37°
15'
76° 25'
<10%
10-40%
40-70%
70-100%
0
1
KILOMETER
OCT 31, 1953
Maryus
Perrin
Jenkins Neck
Guinea Marshes
RIVER
YORK
37°
15'
76° 25'

Figure 16. Changes in the distribution and abundance of SAV at Jenkins Neck in the York River, 1937-1978.

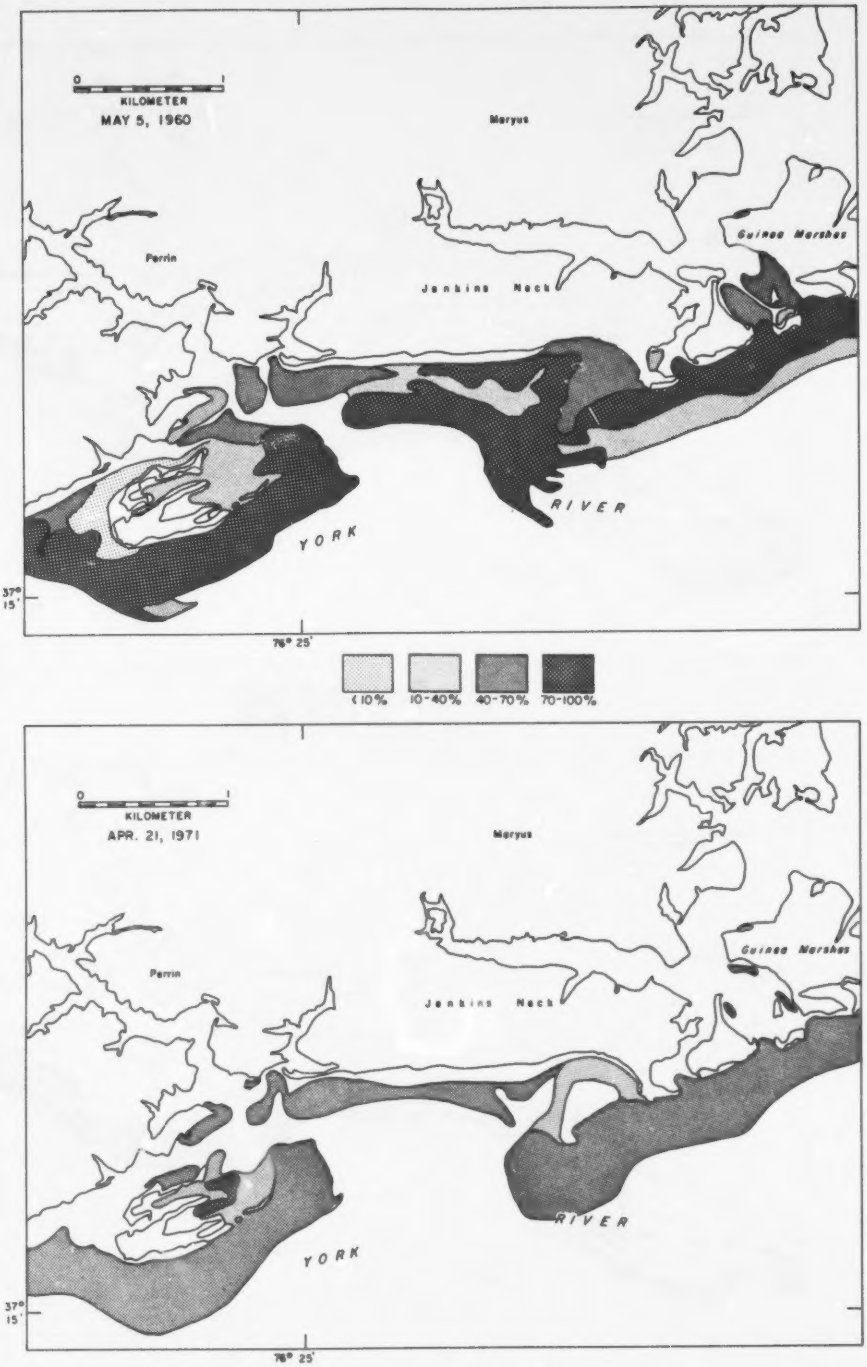

0
1
KILOMETER
MAY 5, 1960
Maryus
Perrin
Jenkins Neck
Guinea Marshes
YORK
RIVER
37°
15'
76° 25'
<10%
10-40%
40-70%
70-100%
0
1
KILOMETER
APR. 21, 1971
Maryus
Perrin
Jenkins Neck
Guinea Marshes
YORK
RIVER
37°
15'
76° 25'

Figure 16. (Continued)

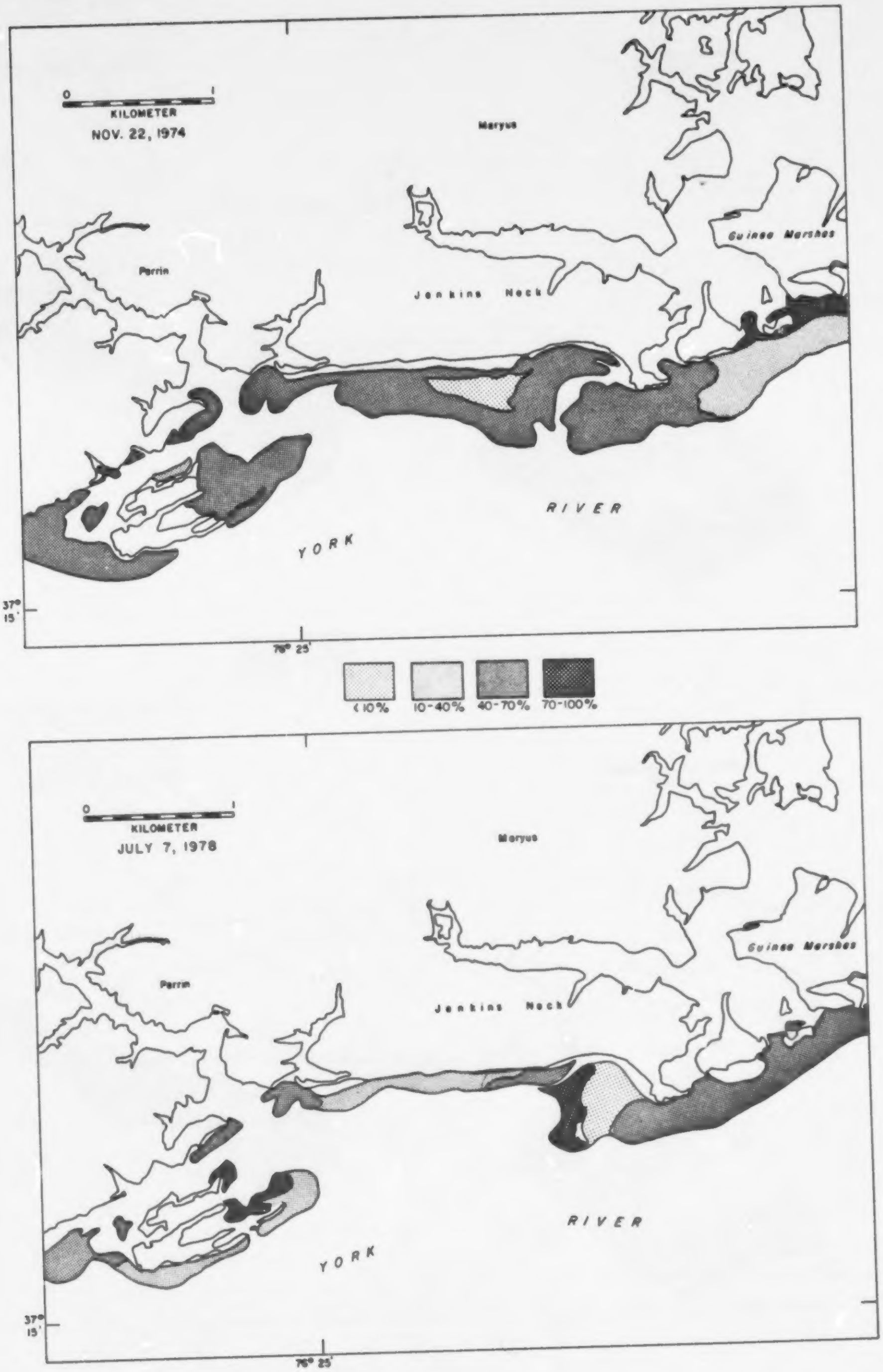

0
1
KILOMETER
NOV. 22, 1974
Maryus
Perrin
Jenkins Neck
Guinea Marshes
YORK
RIVER
37°
15'
76° 25'
<10%
10-40%
40-70%
70-100%
0
1
KILOMETER
JULY 7, 1978
Maryus
Perrin
Jenkins Neck
Guinea Marshes
YORK
RIVER
37°
15'
76° 25'

Figure 16. (Continued)

East River (Table 4; Fig. 17)

The area at the mouth of the East River encompasses a broad, shoal area. In 1937, 3.27 x 10^6 m^2 of this area contained SAV (most likely *Ruppia* and *Zostera*) with 55% of this area in very sparce to sparce vegetation. By 1953, this area had increased to 4.88 x 10^6 m^2 of SAV with 65% in moderate to dense stands of grass. The total area of SAV was similar in 1963, but there were no dense areas. The fact that the photograph was taken during the fall period probably accounted for most of the area being classified as sparce to moderate. In 1971, the total area was 4.30 x 10^6 m^2, similar to the data for 1953 and 1963. 35% reduction of SAV occurred between 1971 and 1974, with the greatest decrease occurring along the outer limits of the beds where *Zostera* normally dominates.

There was a 13% reduction between 1974 and 1978, when only 2.42 x 10^6 m^2 were covered with SAV. The outer edges of this area which previously had sparce coverage of SAV in 1978 were devoid of any grass although the habitat was suitable for SAV growth, as indicated by previous data for 1953 to 1971.

Vaucluse Shores (Table 4; Fig. 18)

This area represents the only anomalous pattern to the SAV distribution. Despite the supposedly large scale reductions in *Zostera* around the Bay region in the early 1930's, there apparently were still extensive grass beds in this region (assumed to be *Zostera* and *Ruppia*). In 1938, it is estimated that a total of 4.05 x 10^6 m^2 of SAV existed. This total area of coverage remained approximately the same in 1955, 1966 and 1972 despite some changes in the distribution pattern. The 1978 data showed the total area declined to 2.81 x 10^6 m^2. Thus over the last 40 years, this area has fluctuated the least in total grass bed area of all studied. It is significant to note that the grass bed alterations in this area are apparently due to the dynamics of the sandbars and sandpits found in this region. Both features have migrated and altered the contour of the shallows. Accompanying the changes in bar and spit formation were changes in grass bed distribution. As the bars and spits moved and caused certain habitats to become unsuitable for SAV survival, other areas become suitable with migration of SAV into them. Evidence for this can be found in cores taken in the sand bar region adjacent to grass beds. Cores taken to depths of 1 meter contained remnants of eelgrass rhizomes at the core bottom. These rhizome fragments were found closer to the surface as the existing grass bed was approached. In the north section of the bed the area was found to be shoaling. The habitat therefore has become more suitable for *Ruppia* than *Zostera*. General observations of sections of this northern part made between 1976 and 1978 indicated changes in species composition from *Zostera* to *Ruppia*. In addition sediment cores taken in these predominately *Ruppia* areas indicate dense *Zostera* rhizomes in close proximity to the sediment surface, confirming that *Zostera* was recently present. Thus, it appears, that geological processes such as sediment transport are very important determinants in SAV distribution here.

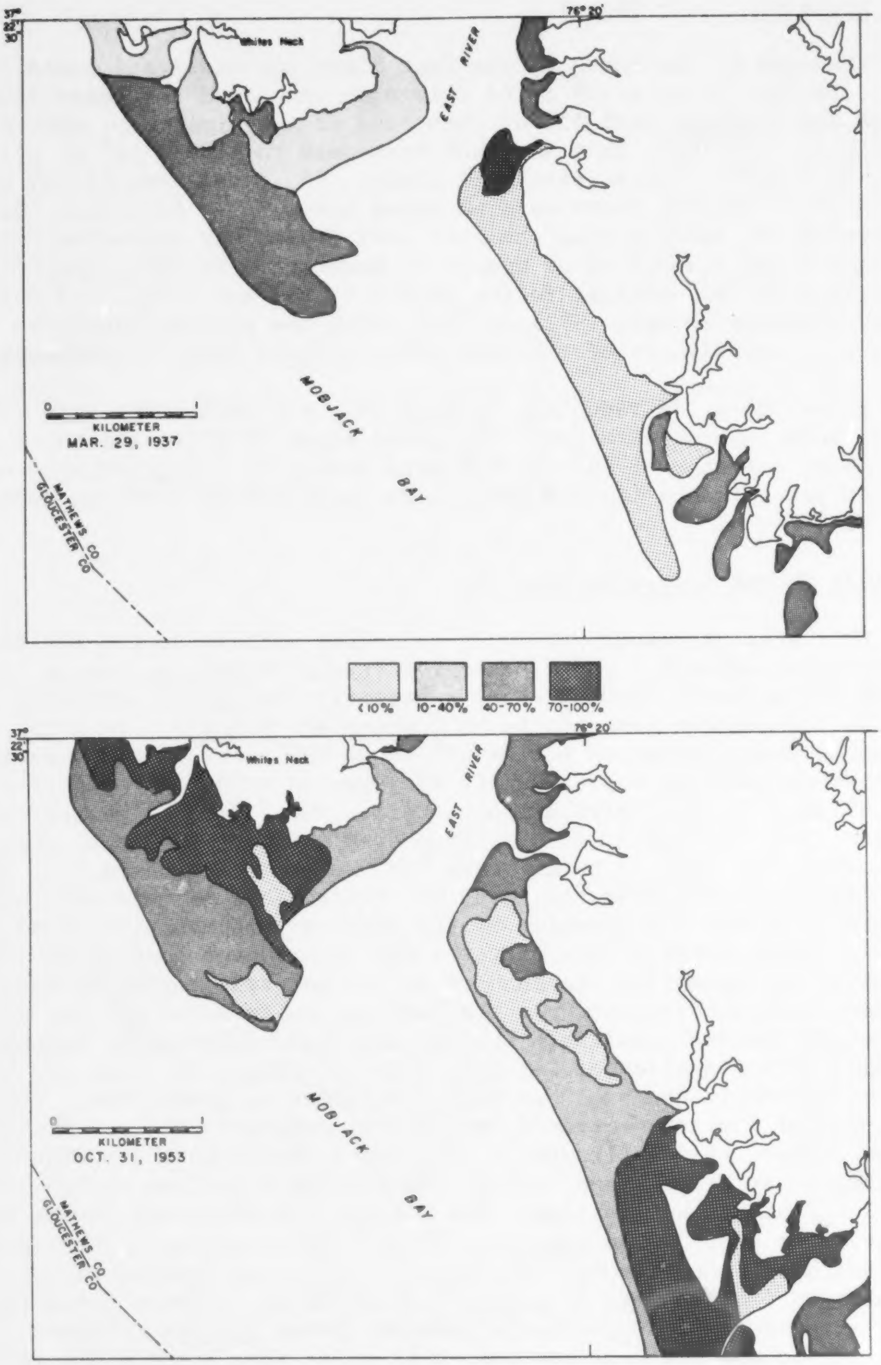

37° 22' 30"
76° 20'
Whites Neck
EAST RIVER
MOBJACK BAY
0
1
KILOMETER
MAR. 29, 1937
MATHEWS CO
GLOUCESTER CO
<10%
10-40%
40-70%
70-100%
37° 22' 30"
76° 20'
Whites Neck
EAST RIVER
MOBJACK BAY
0
1
KILOMETER
OCT. 31, 1953
MATHEWS CO
GLOUCESTER CO

Figure 17. Changes in the distribution and abundance of SAV at the East River, Mobjack Bay, 1937-1978.

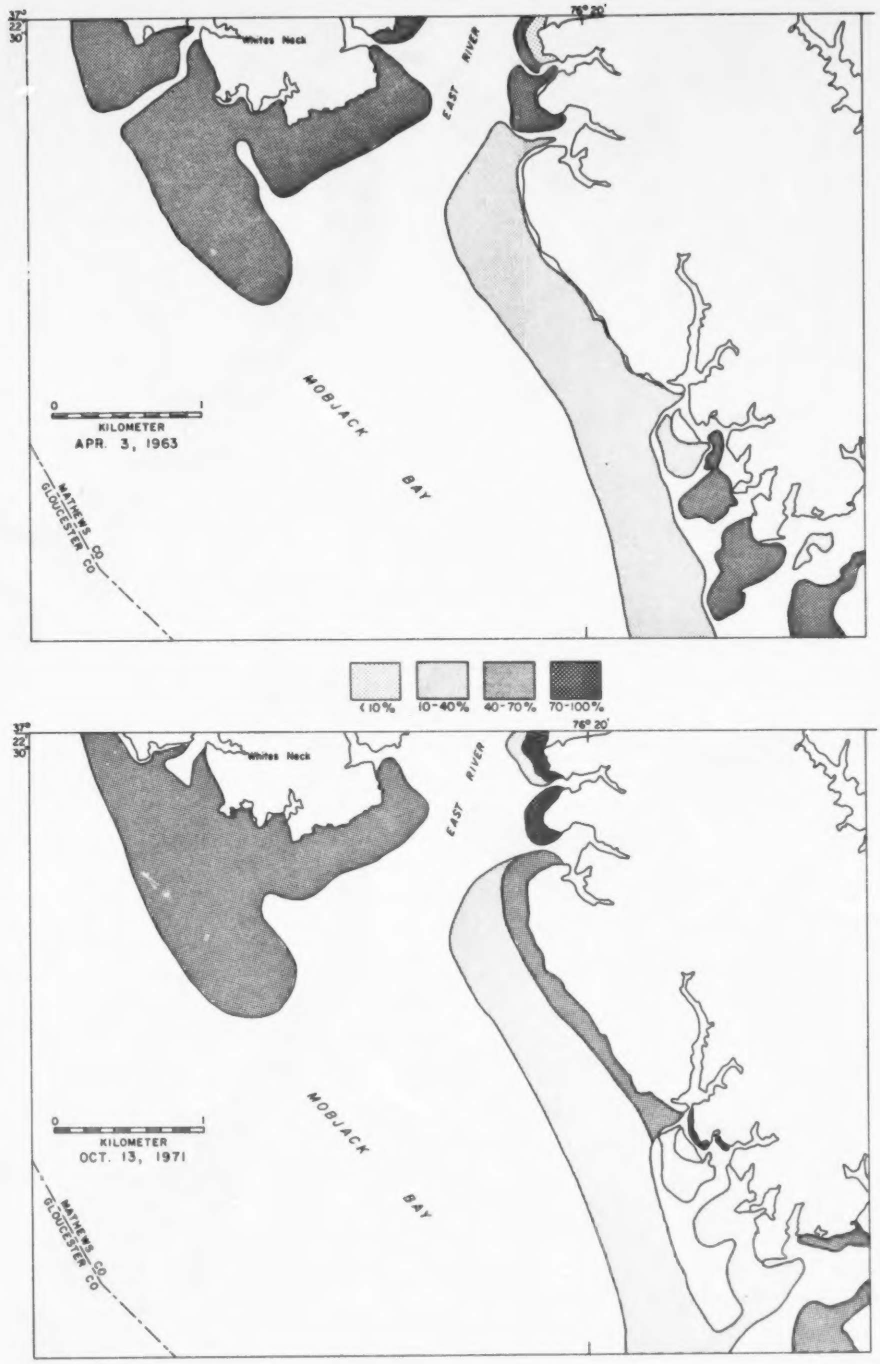

37°
22'
30"
76° 20'
Whites Neck
EAST RIVER
MOBJACK BAY
0
1
KILOMETER
APR. 3, 1963
MATHEWS CO
GLOUCESTER CO
< 10%
10-40%
40-70%
70-100%
37°
22'
30"
76° 20'
Whites Neck
EAST RIVER
MOBJACK BAY
0
1
KILOMETER
OCT. 13, 1971
MATHEWS CO
GLOUCESTER CO

Figure 17. (Continued)

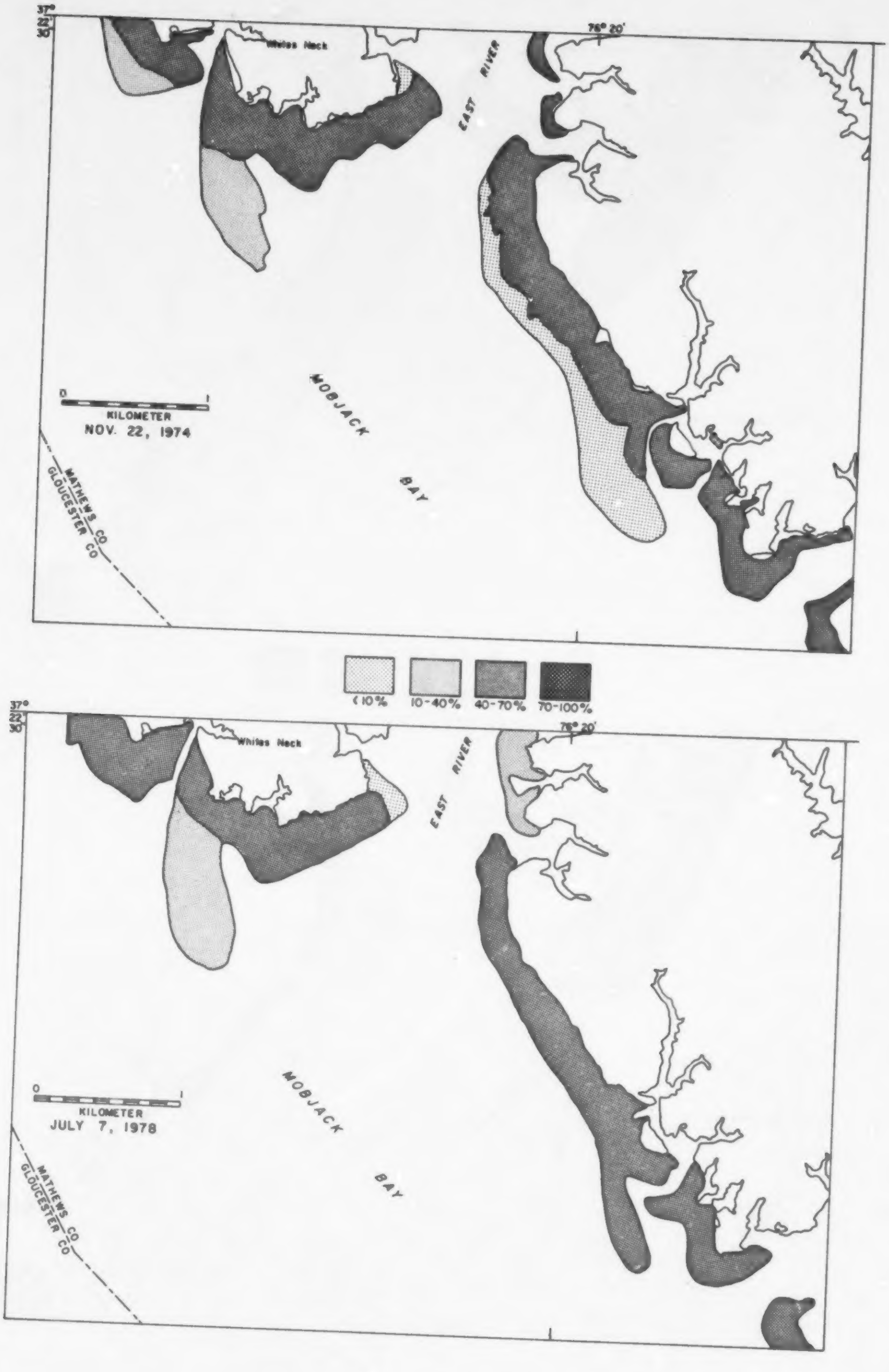

37°
22'
30"
Whites Neck
76° 20'
EAST RIVER
0
1
KILOMETER
NOV. 22, 1974
MOBJACK
BAY
MATHEWS CO
GLOUCESTER CO
<10%
10-40%
40-70%
70-100%
37°
22'
30"
Whites Neck
76° 20'
EAST RIVER
0
1
KILOMETER
JULY 7, 1978
MOBJACK
BAY
MATHEWS CO
GLOUCESTER CO

Figure 17. (Continued)

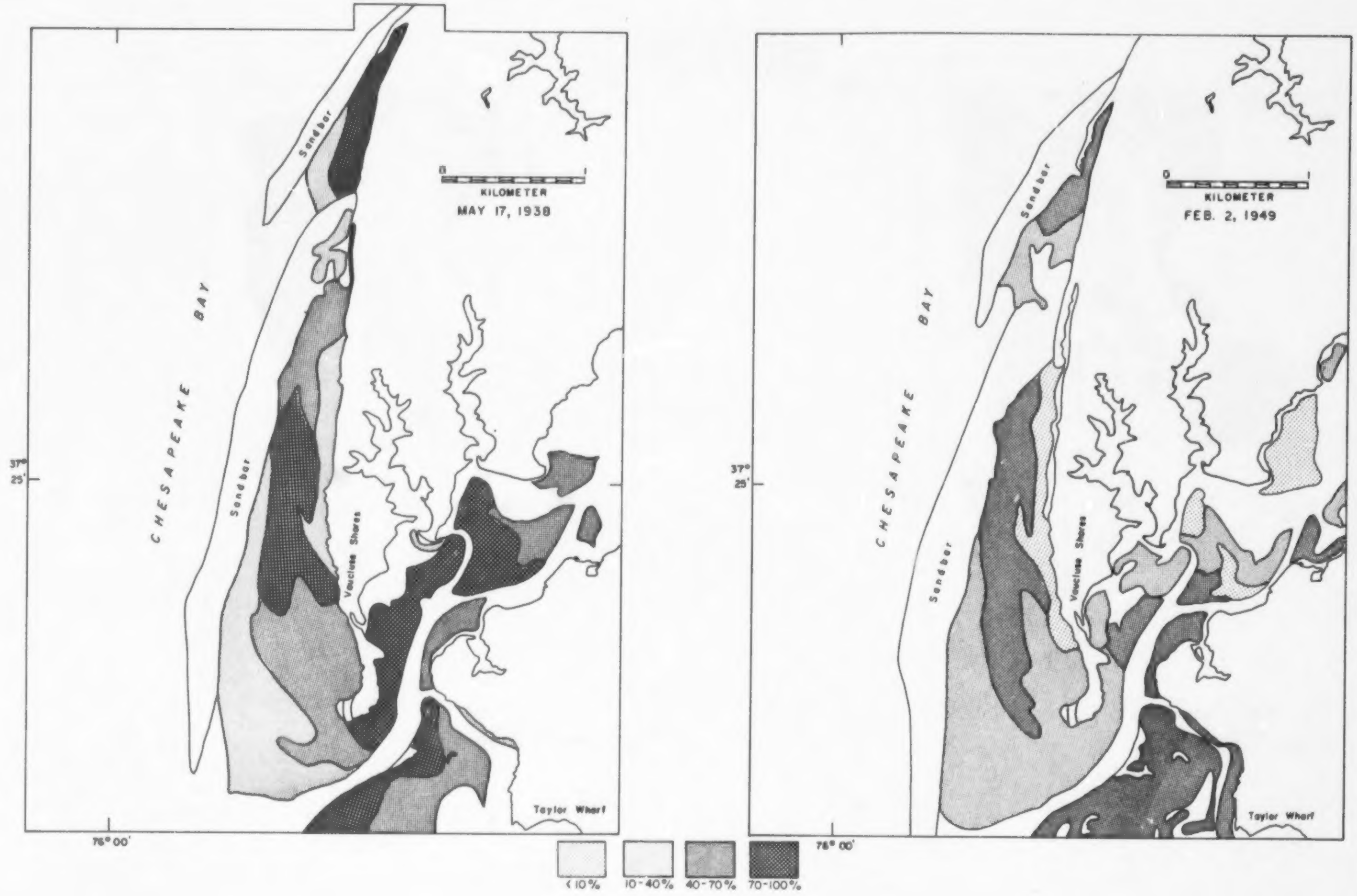

Sandbar
CHESAPEAKE BAY
Sandbar
Vaucluse Shores
0
1
KILOMETER
MAY 17, 1938
Taylor Wharf
37°
25'
76° 00'
Sandbar
CHESAPEAKE BAY
Sandbar
Vaucluse Shores
0
1
KILOMETER
FEB. 2, 1949
Taylor Wharf
37°
25'
76° 00'
<10%
10-40%
40-70%
70-100%

Figure 18. Changes in the distribution and abundance of SAV at Vaucluse Shores on the Eastern Shore, 1938-1978.

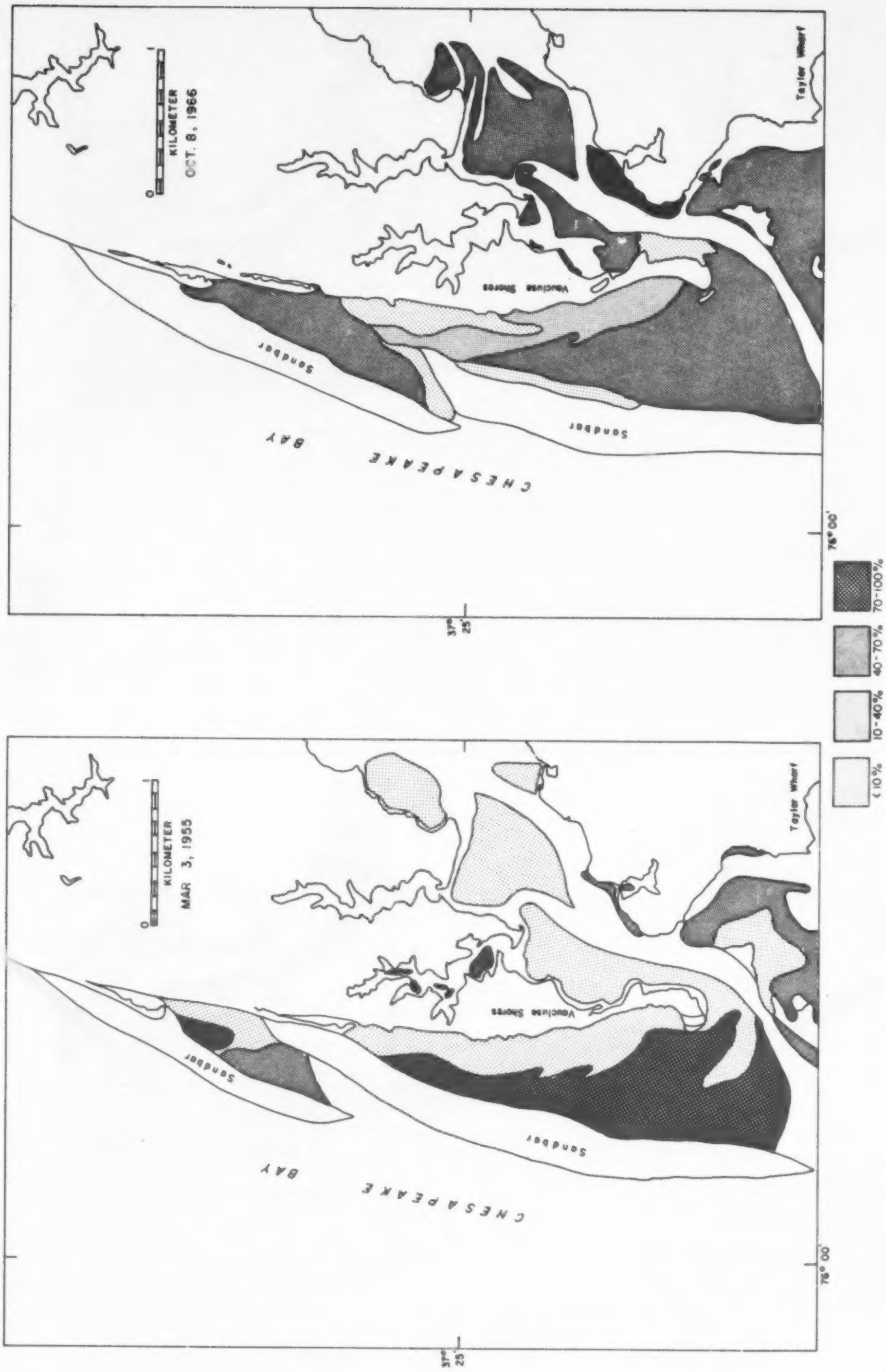

KILOMETER
0
1
OCT. 8, 1966
MAR 3, 1955
CHESAPEAKE BAY
Sandbar
Vaucluse Shores
Taylor Wharf
37° 25'
76° 00'
<10%
10-40%
40-70%
70-100%

Figure 18. (Continued)

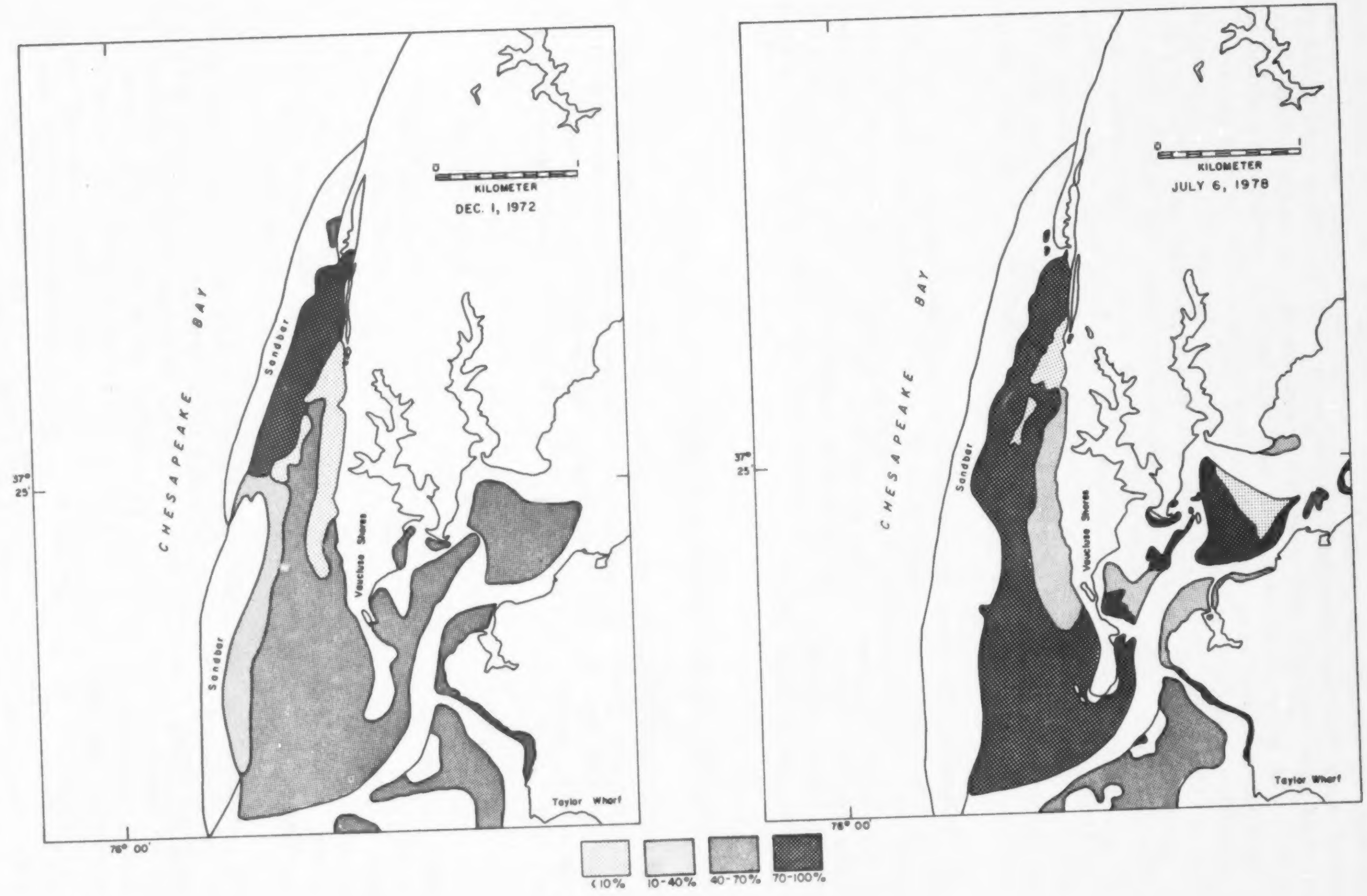

0
1
KILOMETER
DEC. 1, 1972
CHESAPEAKE BAY
Sandbar
Sandbar
Vaucluse Shores
Taylor Wharf
37° 25'
76° 00'
0
1
KILOMETER
JULY 6, 1978
CHESAPEAKE BAY
Sandbar
Vaucluse Shores
Taylor Wharf
37° 25'
76° 00'
<10%
10-40%
40-70%
70-100%

Figure 18. (Continued)

The distribution of SAV (Ruppia and Zostera) in the last 40 years, as delineated by changes in grass bed coverage in the six specific areas, showed a very reduced coverage in the late 1930's. This coincided with the period when Zostera had also declined along the entire East Coast of the U.S. The only anomalous area was the eastern shore site which showed a more extensive grass area than the other sites. The period between 1937 and 1953 showed a dramatic increase in area coverage as well as increase in density of the beds. The increase continued through the 1960's and in some areas until 1971-1972. Slight decreases were observed during this period at Mumfort Island, Jenkins Neck and Parrott Island. The largest decrease of SAV in all areas occurred between 1971 and 1974 and more specifically in 1973 (Orth and Gordon, 1975; Orth, 1976). Both area coverage and the density of the beds showed a significant decrease. This decrease continued through 1978 when the distribution and abundance of SAV in each area was the smallest observed in the last 40 years.

In reviewing the past and present data, the distribution and abundance of SAV in these selected areas in 1978 is very similar to the data collected of 1937-1938. This suggests that, perhaps, whatever factor or factors caused the major decline of the grass beds in the 1930's may also have been operating in the 1970's. The possible cause(s) for the recent decline of SAV in the Chesapeake Bay are numerous and have been thoroughly discussed by Stevenson and Confer (1978).

TRANSECT ANALYSIS OF MESOHALINE AND POLYHALINE SAV BEDS

Data obtained from the seventeen transects located at six areas around the lower Bay are found in Appendix D. Location of each transect is displayed on the appropriate topographic quadrangle in Appendix B. The sampling areas, number of transects and topographic quadrangles are as follows:

Area	No. Transects	Quadrangles
Plum Tree Island	2	Poquoson East
Brown's Bay	2	Achilles
Ware Neck	2	Achilles
East River	2	New Point Comfort
Horn Harbor	2	New Point Comfort
Vaucluse Shores	7	Franktown

The large, mesohaline SAV beds sampled by the seventeen transects were found to be composed almost exclusively of a mixture of Zostera marina and Ruppia maritima. At only one location, Vaucluse Shores, transect F, was another species, Zannichellia palustris, recorded. Comparisons of individual transects showed a consistent pattern of distinct zonation. Ruppia occupied the near shore, shallow areas and graded to mixed zones of Ruppia and Zostera. At greater depths, Ruppia ended and Zostera was the only species found. The size of each of these three zones varied greatly and in some areas was not present at all. The primary controlling factor for the configuration of this zonation appeared to be depth and, therefore, bottom topography, although site exposure also seemed important. Salinity did not appear to be much of a factor within each bed but could be important in comparing different sites. Temperature and turbidity were probably also important but were controlled to a great extent by water depth. At different sites however, variations in turbidity probably controlled the depths to which the two species will occur. In the least turbid areas both species grew to the greatest depths.

Comparisons of the percent cover data with the biomass measurements made at the Vaucluse Shores site indicated significant positive correlations. Table 5 presents the data obtained at approximately 50 m intervals along the Vaucluse Shores transects. Because of difficulties associated with determining numbers of shoots of Ruppia as well as separating the above ground and below ground portions of the plants, only total biomass is presented for that species. Product-moment correlations calculated between the percent cover estimates and the number of shoots of Zostera, total weight of Zostera, above ground and below ground weights of Zostera, and total weights of Ruppia per 0.1 m^2 are presented in Table 6. All are significant at the 1% level, indicating that percent cover provided a good estimation of the amount of vegetation present.

Means of 741 shoots per m^2 and 78.2 g per m^2 were obtained for those samples containing Zostera during this August, 1978, transect sampling. These numbers compared favorably with the more complete seasonal data obtained at the Vaucluse Shores site for another project (Figure 12). No data were available for comparison with the Ruppia which had a mean total weight of 43.2 g per m^2. It appears that the data collected at Vaucluse Shores during the transects reflects the maximum seasonal standing stock of Zostera. Although the observations made at the other transect sites around the lower Bay followed the Vaucluse Shores work by several weeks to a month, there seemed to be no great deterioration of the beds during that time. It is therefore assumed that the data obtained during all the transects reflect near maximum standing stock conditions.

Percent cover data for the seven Vaucluse Shores transects were summed and the means and standard deviation of the means determined for each 1 dm depth interval. This provided a composite picture of how the two submerged species varied with depth throughout the entire bed (Figure 19). The standard deviations were quite large since all observations at each depth were averaged, including those with no SAV present. The distinct zonation with depth was evident for the two species, with Ruppia dominating the shallow depths and Zostera most abundant at the greater depths. Ruppia was found to exhibit a significant percent cover (>5%) from +1 to -9 dm mean low water (MLW). Maximum percent cover for Ruppia occurred at -3 dm depths. Zostera on the other hand occurred at -10 dm MLW. Both exhibited a greater range of depths with Ruppia recorded from +2 to -10 dm MLW and Zostera from +1 to -13 dm MLW. In general Ruppia was found dominant in the shallow more protected area of +1 to -4 dm MLW with Ruppia and Zostera co-occurring at intermediate depths of -4 to -8 dm MLW. Zostera dominated at the greater depths of -8 to -12 dm and in the most exposed sites. These ranges of depths were characteristic of the other transected areas around the lower Bay, although the specific depth ranges varied from site to site.

TABLE 5. PERCENT COVER, DENSITY, BIOMASS OF ZOSTERA AND RUPPIA - VAUCLUSE SHORES TRANSECT SAMPLES, AUGUST, 1978

Sample #	Zostera % cover	Zostera #/0.1m^2	Zostera Total wt. (g)	Zostera Aboveground wt. (g)	Zostera Roots-Rhizomes wt. (g)	Ruppia % cover	Ruppia Total wt.
A2	40	81	9.07	4.25	4.82	60	8.20
A3	5	23	2.72	1.28	1.44	60	3.92
A4	25	51	5.97	3.42	2.55	75	6.30
A5	80	119	14.84	8.79	6.05	20	3.70
A6	90	107	13.38	7.15	6.23	10	5.63
A7	45	37	4.35	2.11	2.24	45	3.11
A8	95	113	12.77	7.59	5.18	5	NA
A9	75	62	5.75	3.49	2.26	1	0.03
A10	80	82	12.23	7.75	4.48	0	0
A11	90	95	9.63	6.36	3.27	0	0
A12	80	112	12.15	7.09	5.06	0	0
A13	85	125	11.89	5.4	6.49	5	0.11
A14	95	180	20.74	12.42	8.32	1	0.01
B_1	95	103	11.74	7.97	3.77	1	0.02
B_2	80	81	9.32	6.21	3.11	0	0
B_3	90	86	8.29	5.45	2.84	0	0
B_4	100	133	19.76	13.51	6.25	0	0
B_5	60	115	7.27	4.94	2.33	40	2.39
B_6	100	108	9.85	6.19	3.66	0	0
B_8	0	0	0	0	0	100	10.13
B_9	0	0	0	0	0	50	2.38
B_{10}	0	0	0	0	0	100	9.09
B_{11}	0	0	0	0	0	100	4.73
C_1	0	0	0	0	0	100	3.08
C_2	0	0	0	0	0	90	4.41
C_3	20	25	3.10	1.71	1.39	40	2.80
C_4	0	1	0.02	0	0.02	50	3.02
C_5	0	0	0	0	0	90	5.43
C_6	40	87	5.45	2.34	3.11	30	2.55

(continued)

TABLE 5 (continued)

Sample #	*Zostera* % cover	*Zostera* #0.1m^2	*Zostera* Total wt. (g)	*Zostera* Aboveground wt. (g)	*Zostera* Roots-Rhizomes wt. (g)	*Ruppia* % cover	*Ruppia* Total wt.
C_7	0	0	0	0	0	99	8.09
C_8	15	20	1.45	0.74	0.71	0	0
D_1	0	0	0	0	0	5	1.19
D_2	1	9	0.55	0.55	0	90	7.76
E_6	0	0	0	0	0	100	9.41
F_1	0	0	0	0	0	100	4.92

TABLE 6. PRODUCT MOMENT CORRELATION (r) OF PERCENT COVER OF ZOSTERA AND RUPPIA VERSUS NUMBER OF SHOOTS, TOTAL ABOVEGROUND, AND ROOT AND RHIZOME WEIGHTS FOR VAUCLUSE SHORES TRANSECTS, AUGUST 1978

Comparison of percent cover vs.	r	N
Zostera Number of shoots/0.1m^2	0.93**	35
Zostera Total wt.0.1m^2	0.93**	35
Zostera Aboveground wt./0.1m^2	0.92**	35
Zostera Roots-Rhizomes wt./0.1m^2	0.87**	35
Ruppia Total wt.0.1m^2	0.85**	34

**significant at 0.01 level.

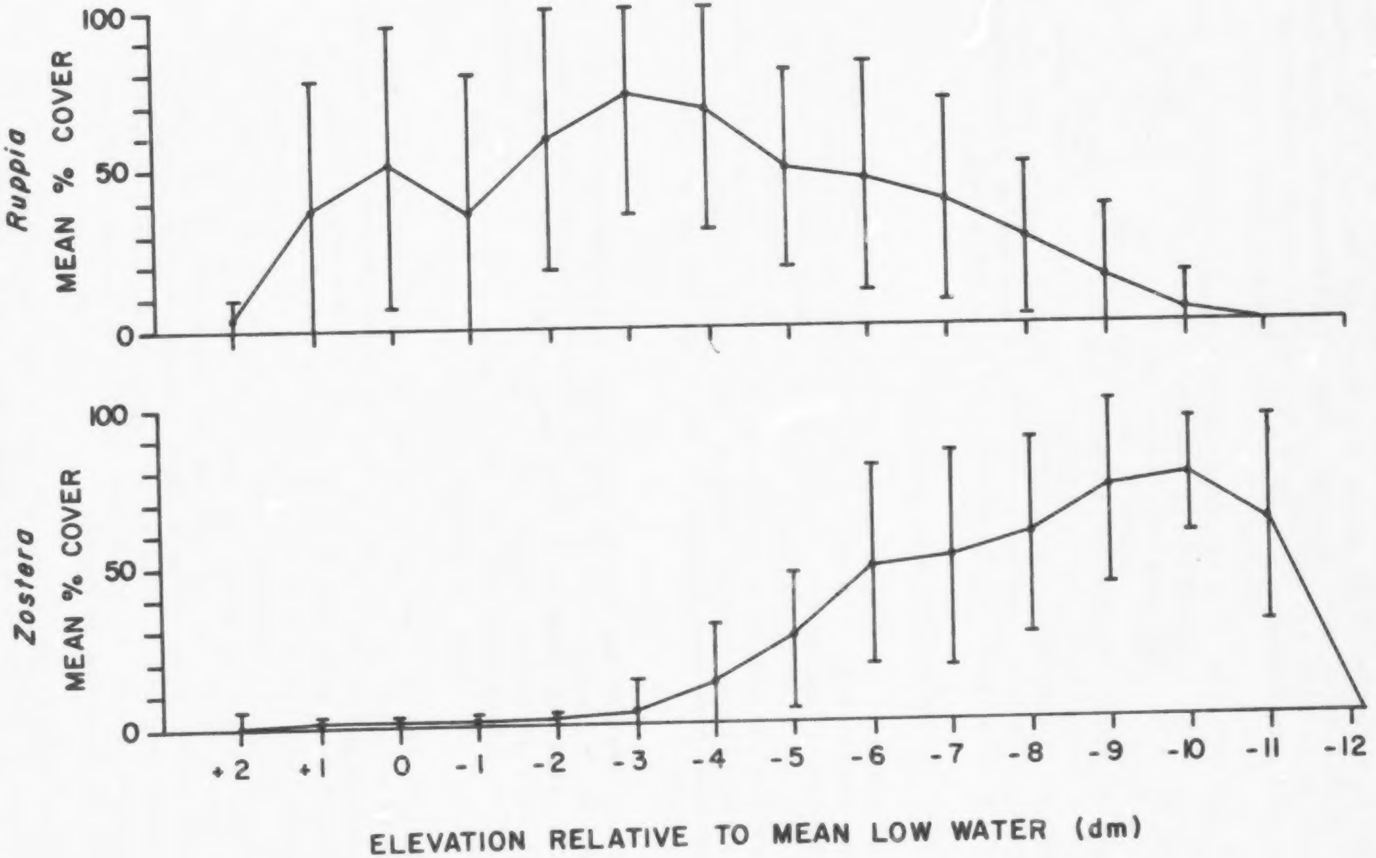


Figure 19. Relationship between percent cover and depth for Zostera and Ruppia at Vaucluse Shores. Brackets indicate standard deviation.

Bottom types found at the 17 transects varied from silts to coarse sands with fine sand being the most common designation. Another bottom type observed in a few SAV beds around the lower Bay was of relic oyster bars covered with a fine layer of silty sand. Variations in bottom types did not appear to be directly related to speciation within the beds as both species were associated with each of the sediment types.

Table 7 presents the relative importance values calculated for each species at each of the transects. At the Vaucluse Shores area Ruppia appears to be the most important species across 6 of the 7 transects. As illustrated in Figure 19 this seemed to be depth related. At the other transects located along the western shore of the Bay both Zostera and Ruppia varied in importance, with Zostera most important in some areas and Ruppia in others. These data indicated that although Zostera has long been recognized as the dominant species in Virginia's mesohaline and polyhaline SAV beds, the importance of Ruppia should not be underestimated.

Plum Tree Island (Poquoson East quadrangle)

Figure 20 presents profile diagrams of the two transects conducted at the Plum Tree Island area. The SAV in this region was characterized by a nearly continuous fringing bed beginning just below MLW and extending offshore for varying widths, depending upon bottom topography. The adjacent shoreline was one of extensive brackish marshes composed largely of Spartina alterniflora, Spartina patens and Juncus roemerianus. Salinities recorded here were between 20 to 21 ppt and water temperatures approximately 24°C.

The width of the SAV bed at transect A was quite narrow (<150 m) with the bottom rapidly increasing in depth from the marsh shoreline outward. Apparently as a result of both this relatively steep shore and the high wave energy at this site only Zostera was present. This seems reasonable considering the extensive root and rhizomes system of Zostera and less extensive below ground system of Ruppia.

In contrast to the narrowness and steep slope of transect A, transect B located several kilometers to the north was characterized by an extremely broad zone of submerged vegetation. From the adjacent marsh shoreline, the bottom dropped to a wide trough vegetated by a sparse coverage of Ruppia. Although this portion of the transect had water depths suitable for the growth of Zostera, none was found. Zostera did occur in a narrow zone as the bottom gradually began to rise to a broad offshore bar. At the shallowest portions of the bar (<1 dm MLW) dense stands of Ruppia were mixed with intermittent areas of open sand. Continuing offshore, the depths again increased, and on this slope Ruppia was gradually replaced by Zostera. At approximately -8 dm MLW the vegetation ceased, although the bottom continued to increase in depth.

The effect of site exposure was evident along the offshore slope of transect B. At 800 m to 1000 m from shore, with elevations of -2 dm to -5 dm, large patches of exposed roots and rhizomes of Zostera were observed. The weather preceeding the sampling of this transect had consisted of

TABLE 7. SUMMARY OF TRANSECT ANALYSES, INCLUDING IMPORTANCE VALUES, FOR SEVENTEEN TRANSECTS ACROSS SAV BEDS IN THE LOWER CHESAPEAKE BAY

TRANSECT	SPECIES	TOTAL PLOTS	PLOTS OF OCCURRENCE	PERCENT FREQUENCY	TOTAL COVER (%)	AVERAGE COVER (%)	RELATIVE FREQUENCY (%)	RELATIVE COVER (%)	IMPORTANCE VALUE
Plum Tree Island A	*Zostera*	13	5	38.5	121.	9.3	100.0	100.0	200.0
Plum Tree Island A	*Ruppia*	13	0	0	0	0	0	0	0
Plum Tree Island B	*Zostera*	110	50	45.4	1615.	14.7	42.0	51.7	93.7
Plum Tree Island B	*Ruppia*	110	69	62.7	1508.	13.7	58.0	48.3	106.3
Brown's Bay A	*Zostera*	37	33	89.2	1912.	51.7	68.7	91.7	160.4
Brown's Bay A	*Ruppia*	37	15	40.5	173.	4.7	31.3	8.3	39.6
Brown's Bay B	*Zostera*	40	37	92.5	1623.	40.6	55.2	53.9	109.1
Brown's Bay B	*Ruppia*	40	30	75.0	1390.	34.7	44.8	46.1	90.9
Ware Neck A	*Zostera*	34	17	50.0	415.	12.2	53.1	35.3	88.4
Ware Neck A	*Ruppia*	34	15	44.1	760.	22.4	46.9	64.7	111.6
Ware Neck B	*Zostera*	37	27	73.0	1008.	27.2	55.1	46.9	102.0
Ware Neck B	*Ruppia*	37	22	59.5	1140.	30.8	44.9	53.1	98.0
East River A	*Zostera*	29	14	48.3	583.	20.1	42.4	34.8	77.2
East River A	*Ruppia*	29	19	65.5	1094.	37.7	57.6	65.2	122.8
East River B	*Zostera*	35	17	48.6	260.	7.4	48.6	16.6	65.2
East River B	*Ruppia*	35	18	51.4	1305.	31.3	51.4	83.4	134.8
Horn Harbor A	*Zostera*	40	26	65.0	991.	24.8	89.6	91.7	181.3
Horn Harbor A	*Ruppia*	40	3	7.5	90.	2.3	10.4	8.3	18.7

(continued)

TABLE 7 (continued)

TRANSECT	SPECIES	TOTAL PLOTS	PLOTS OF OCCURRENCE	PERCENT FREQUENCY	TOTAL COVER (%)	AVERAGE COVER (%)	RELATIVE FREQUENCY (%)	RELATIVE COVER (%)	IMPORTANCE VALUE
Horn Harbor B	*Zostera*	57	35	61.4	1197.	21.0	83.4	94.3	177.7
Horn Harbor B	*Ruppia*	57	7	12.3	72.	1.3	16.6	5.7	22.3
Vaucluse Shores A1	*Zostera*	42	34	80.9	1192.	28.4	46.6	33.8	80.4
Vaucluse Shores A1	*Ruppia*	42	39	92.8	2339.	55.7	53.4	66.2	119.6
Vaucluse Shores A	*Zostera*	75	62	82.7	3367.	44.9	59.0	60.6	119.6
Vaucluse Shores A	*Ruppia*	75	43	57.3	2188.	29.2	40.9	39.4	80.3
Vaucluse Shores B	*Zostera*	75	36	48.0	2301.	30.7	42.3	43.9	86.2
Vaucluse Shores B	*Ruppia*	75	49	65.3	2943.	39.2	57.6	56.1	113.7
Vaucluse Shores C	*Zostera*	49	17	34.7	340.	6.9	34.0	13.8	47.8
Vaucluse Shores C	*Ruppia*	49	33	65.3	2943.	39.2	57.6	56.1	113.7
Vaucluse Shores D	*Zostera*	55	13	23.6	258.	4.7	26.0	9.3	35.3
Vaucluse Shores D	*Ruppia*	55	37	67.3	2510.	45.6	74.0	90.7	164.7
Vaucluse Shores E	*Zostera*	37	2	5.4	2.	.05	8.0	.1	8.1
Vaucluse Shores E	*Ruppia*	37	23	62.2	2005.	54.2	92.0	99.9	191.9
Vaucluse Shores F	*Zostera*	20	0	0	0	0	0	0	0
Vaucluse Shores F	*Ruppia*	20	18	90.0	1585.	79.2	85.7	98.7	184.4
Vaucluse Shores F	*Zannichellia*	20	3	15.0	20.	1.0	14.3	1.3	15.6

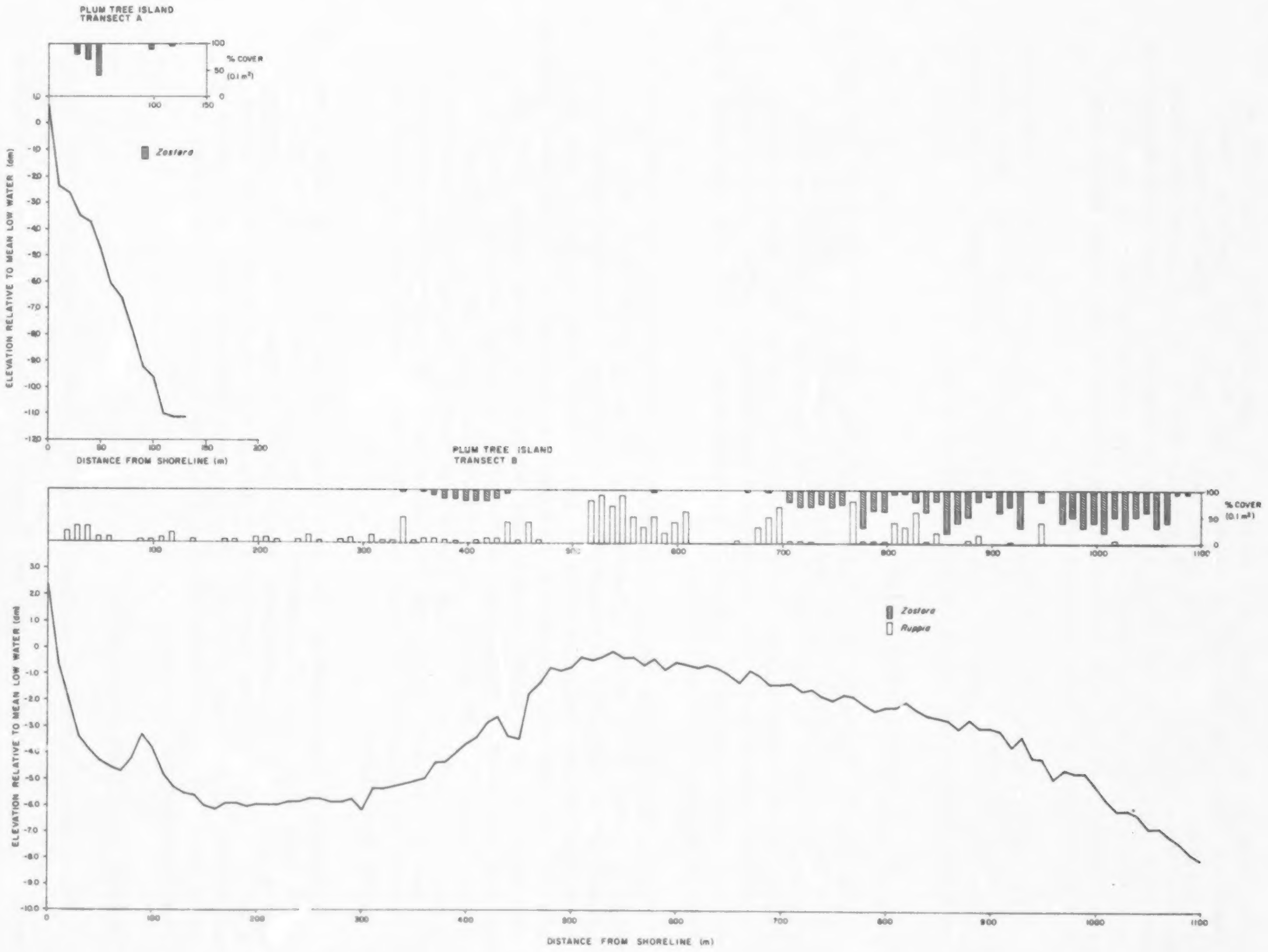


Figure 20. Depth profiles and percent cover estimates for Plum Tree Island transects.

several days of strong northeast winds. It appeared that nearly 10 cm of sand had been removed from portions of the bed. The Zostera looked quite healthy, however, and was being held in place by the remaining uncovered root system. The only Ruppia observed were those plants whose roots were entangled in the Zostera rhizome network. Apparently Ruppia may have difficulty remaining established at exposed locations. A return several weeks later to the same location indicated that fine sands were gradually filling in these exposed areas.

The importance values calculated for both species (Table 1) indicated Ruppia slightly more important than Zostera across transect B. This was primarily due to the greater relative frequency of occurrence of the Ruppia since both species had nearly equal relative cover.

Brown's Bay (Achilles quadrangle)

The Brown's Bay area is a large embayment located along a section of Mobjack Bay. It was characterized by very dense beds of Zostera and Ruppia nearly 400 m in width which were adjacent to extensive marshes dominated by Spartina alterniflora. Salinity values for samples taken while onsite averaged 18 ppt and water temperatures, 29°C. At low slack water one sunny afternoon, however, a temperature of 36°C was recorded in a nearshore Ruppia dominated zone.

Figure 21 presents two profile diagrams illustrating the transects conducted across this area. Transect A, the more northern of the two, was found to be composed predominately of Zostera. The importance value of this species was calculated to be 160.4 while that of Ruppia was 39.6 (Table 7). Of the two transects, transect A appeared to be the more exposed. It was adjacent to a creek channel and subject to strong winds from the north and northeast. Ruppia was never very abundant here and was not observed below -7.5 dm depth. Zostera on the other hand, continued offshore to a depth of -11.0 dm where the bottom continued to increase in depth but no further vegetation was observed. Throughout this transect the bottom was composed of fine sands with some eroded peat adjacent to the marsh shoreline.

Transect B was somewhat the more sheltered of the two in this area with a slope less than that of transect A. Ruppia was observed to be much more abundant here with an importance value of 90.0 versus 109.1 for Zostera (Table 7). For the most part this transect was characterized by dense mixed stands of the two grasses. Ruppia was observed last at a depth of -7.0 dm while Zostera continued to a depth of nearly -10.0 dm along a bottom composed of fine sand.

Ware Neck (Achilles quadrangle)

Two transects were conducted on either side of Ware Neck Point (Figure 22), a narrow peninsula located at the confluence of the Ware and North Rivers. Dense beds of Zostera and Ruppia are found along the lower shorelines of both of these rivers where they connect at Ware Neck Point.

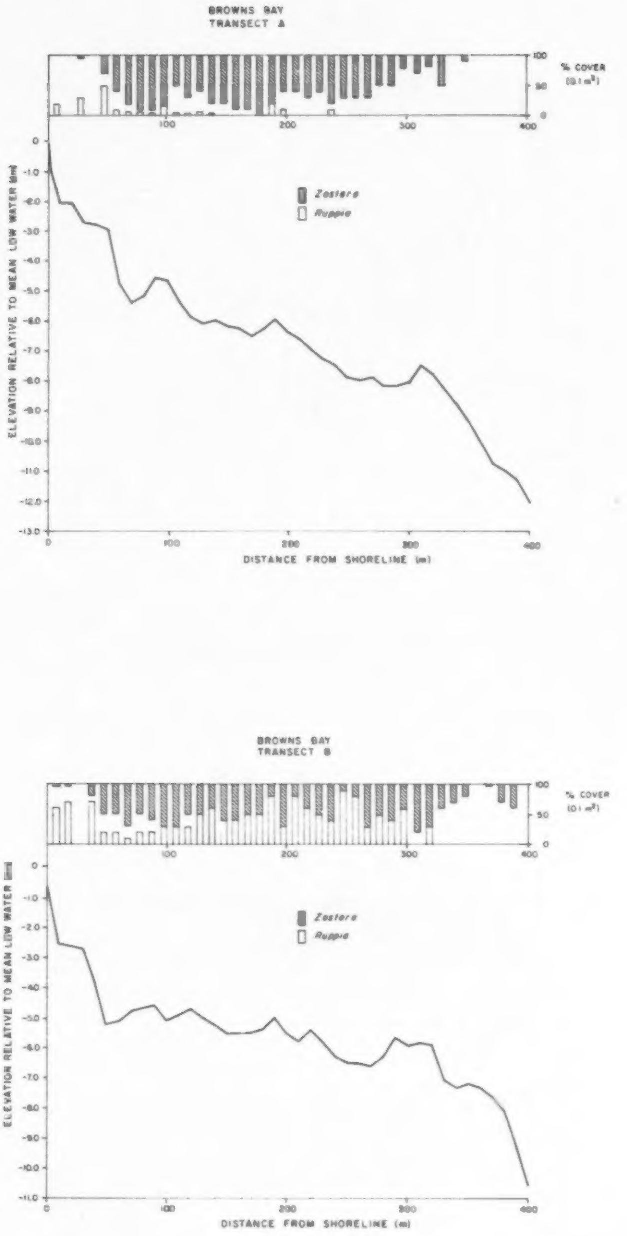


Figure 21. Depth profiles and percent cover estimates for Zostera and Ruppia at Brown's Bay transects.

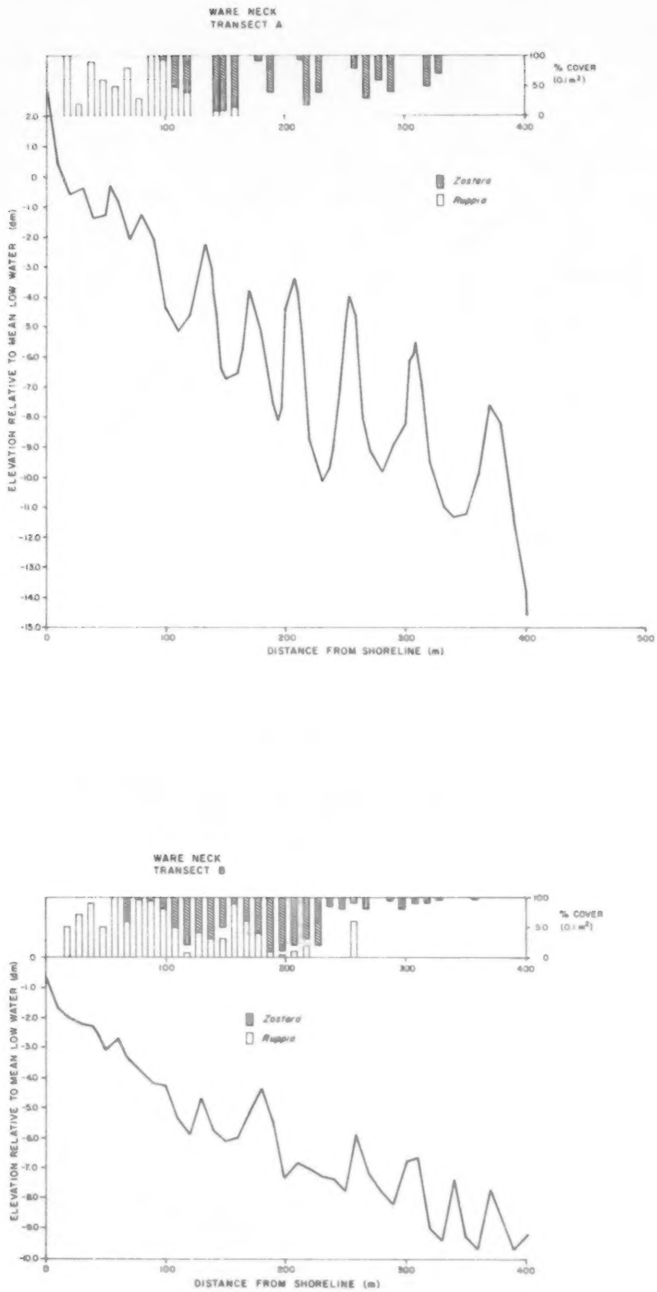


Figure 22. Depth profiles and percent cover estimates for Zostera and Ruppia at Ware Neck transects.

Salinities were found to average 17.5 ppt and water temperatures 30.0°C. The point itself was characterized by a series of radiating, parallel bars separating patches of SAV. Review of historical photographs for this site indicates that these bars have remained relatively stable over the last 20 years.

Transect A was run from a shoreline of sandy beach on the North River side of the point in a direction approximately perpendicular to the radiating bars. The nearshore zone of this transect was characterized by dense stands of Ruppia which began at a depth of near MLW. The first significant bar was observed at a distance of 54 m from shore and was unvegetated at its highest elevation (-0.3 dm). Ruppia continued again on the offshore side of this bar but was absent again at the shallowest portion of the next bar located at a distance of 75 m from shore and an elevation of -1.0 dm. Zostera was first observed in a swale between two bars at a distance of approximately 100 m from shore. Each succeeding bar was unvegetated along its crest although the depths varied only from -2.0 dm to -5.0 dm, elevations suitable for the growth of both Zostera and Ruppia. Interestingly, from 150 m outward, only the offshore slopes of the bars were vegetated until at a distance of 290 m and depth of -9.0 dm, the vegetation ended. Ruppia was last observed at 160 m from shore at a depth of -6.5 dm. From then on the pattern of bar - vegetation - bar consisted solely of Zostera. Integrating the whole transect, Ruppia was found to have an importance value of 111.6 compared to Zostera's 88.4 (Table 7). The greater relative cover by Ruppia, especially in the nearshore zone, was primarily responsible for this dominance.

Transect B was run offshore in similar manner to transect A but on the Ware River side of the point. It was characterized by a series of less distinct bars as well as a broader zone vegetated with Ruppia mixed with Zostera. For the most part both the ridges and swales of the parallel bars were vegetated with grasses, however, the slopes of the bars were much less than that observed along transect A. Ruppia was found to occur offshore to a distance of 260 m and a maximum depth of -7.3 dm. Zostera was observed to be growing at a maximum depth of -9.7 dm nearly 360 m from shore. Importance values for both species were nearly identical, 102.0 for Zostera versus 98.0 for Ruppia (Table 7). Zostera had the greater relative frequency but Ruppia the greater relative cover.

East River (New Point Comfort quadrangle)

The East River is located along the eastern shoreline of Mobjack Bay and was characterized by broad fringing beds of SAV located near its mouth. Few submerged aquatics were recorded within the river system. The shoreline of Mobjack Bay both north and south of the river also consisted of broad areas of submerged aquatics. As with the other areas of SAV around the Bay, Zostera and Ruppia were the only two species found.

Figure 23 presents profile diagrams of the two transects conducted along this region. Transect A was located immediately south of the East River along the Mobjack Bay shoreline and transect B immediately north of

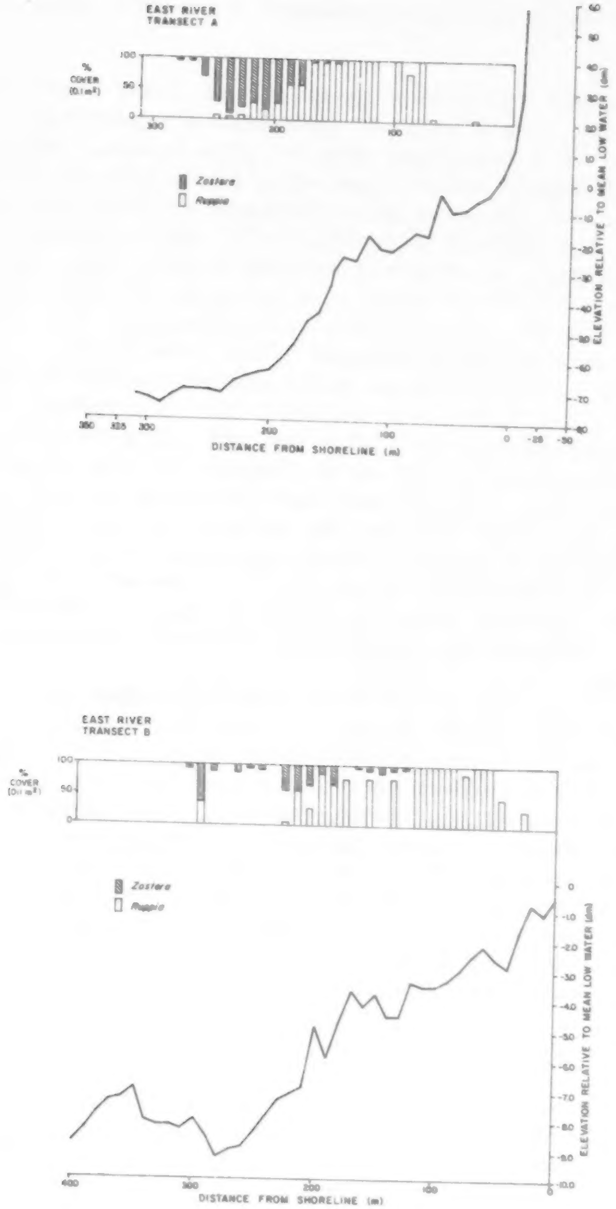


Figure 23. Depth profiles and percent cover estimates for Zostera and Ruppia at East River transects.

the river's mouth. Salinities at both sites averaged 18 ppt and water temperatures varied between 29°C and 32°C.

Transect A was characterized by a nearshore zone of Ruppia grading to an offshore zone of largely Zostera. The shoreline was one of rapidly eroding upland with a fringing marsh of Spartina alterniflora located nearly 10 m offshore. Ruppia was not observed until nearly 30 m from this marsh fringe at a depth of -.07 dm, the intervening bottom was composed largely of coarse sand. Between the 70 m and 170 m distance, Ruppia predominated with dense stands of flowering shoots. At a depth of -0.5 dm and a distance of 175 m, Zostera rapidly increases in abundance and continued its dominance until the end of the grass bed at approximately 300 m. Comparison of the importance values for both species, 122.8 to 77.2 (Table 7), indicates Ruppia to be clearly the most dominant species. It was found to occur at both greater density and relative cover.

The outer edge of the bed consisted of sparse coverage by Zostera along a relatively flat bottom of fine sand. The depth, approximately -7.2 dm, continued without much increase for a considerable distance offshore. Despite the fact that this depth is suitable for growth of Zostera, none was present. A review of the historical aerial photography (see Historical Areas-East River) indicated that as recently as 1974 this area was indeed vegetated with SAV. Reasons for the retreat of the edge bed are as yet undetermined.

Transect B was run offshore from a relatively stable shoreline of Spartina alterniflora dominated marsh. The SAV bed was characterized by a broad, shallow (<-0.5 dm) Ruppia zone grading to a narrow, deeper (>0.5 dm) zone with sparce coverage by Zostera. Again Ruppia had the greater importance value, 134.8 to 65.2 for Zostera (Table 7). Although the relative frequency of both species were similar, Ruppia with its greater relative cover, primarily in the dense nearshore zone, was determined to be the most dominant. A small submerged bar was evident along the outer edge of the bed; however, it was unvegetated and no vegetation was observed beyond the bar.

Horn Harbor (New Point Comfort quadrangle)

Figure 24 presents profile diagrams of the two transects conducted at the Horn Harbor area off Potato Neck. The region is characterized by a shoreline of Spartina alterniflora dominated marsh with an adjacent broad zone of SAV. It lies along the Chesapeake Bay and, as such, is exposed to strong winds and long fetch from the northeast, east, and southeast. Considering this exposure, it was not unusual to find that both transects were dominated by Zostera. At transect A Zostera was found to have an importance value of 181.3 compared to Ruppia's 18.7 (Table 7). Transect B was similar with values of 177.7 and 22.3 for Zostera and Ruppia respectively (Table 7). Salinities were found to average near 18 ppt and water temperatures of 24.5°C were recorded at both sites.

Transect A was characterized by a narrow zone of mixed grasses along the shoreline, rapidly changing to a Zostera dominated community only 50 m

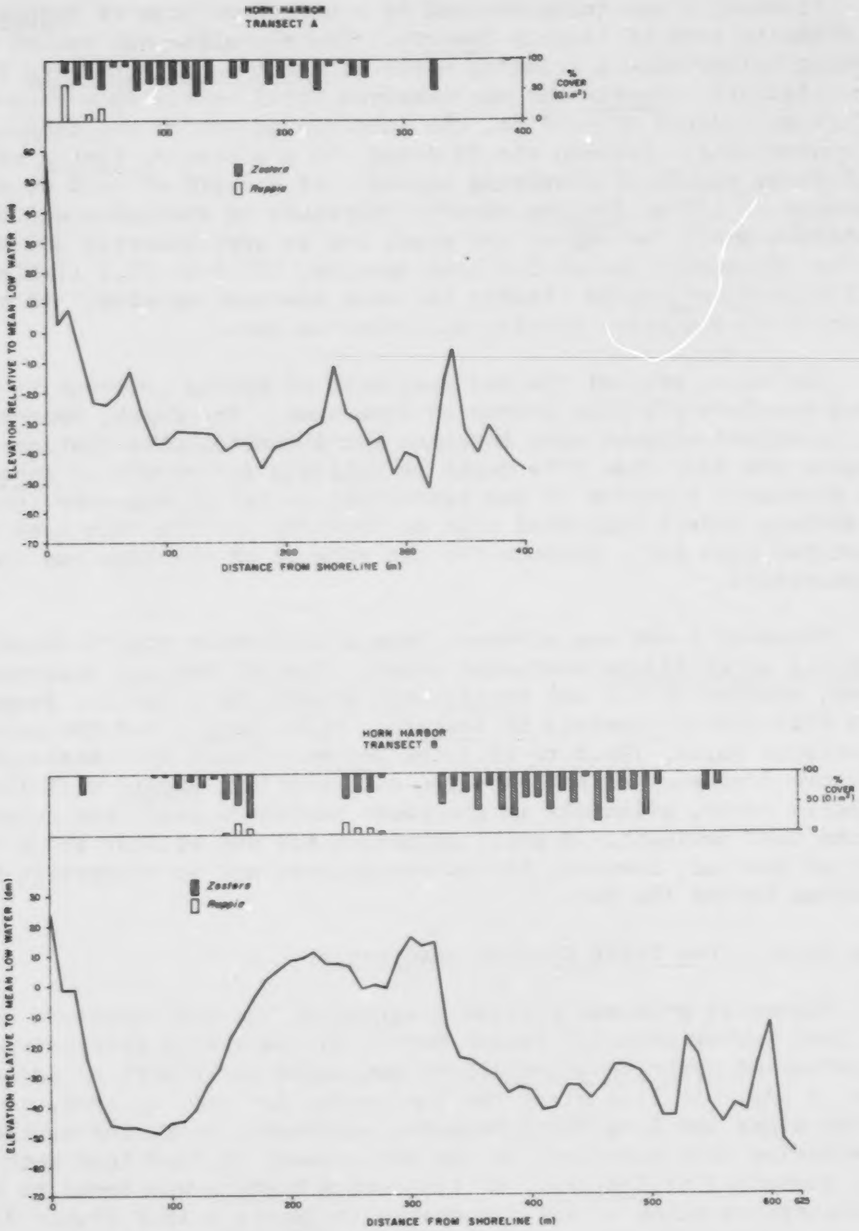


Figure 24. Depth profiles and percent cover estimates for Zostera and Ruppia at Horn Harbor transects.

from shore. *Zostera* was also found to be growing at quite shallow depths here. This transect and transect B to the south were the only two areas where *Zostera* was found above calculated MLW. Since these elevations were only +0.7 dm and +0.6 dm, they are within the error measurements of the technique and may in fact not be above MLW. *Zostera* also appeared to end at much shallower depths here than at any of the other transected areas. It was generally not found below -4.5 dm at either transect, as compared, for example, with -11.0 dm at the Ware Neck site.

On several occasions winds from the south were observed to have resuspended sediments in the area to such an extent that visibility in the water was virtually zero and transect operations had to be halted. Since southerly winds are common during the growing season here, perhaps, the *Zostera* has been relegated to the shallow depths by severe light limitations due to turbidity conditions.

Transect B, located several kilometers south of Transect A, crossed an offshore sandbar vegetated with *Spartina alterniflora* and continued to the outer edge of SAV growth. On the landward side of this bar the area was quite protected and the sediments consisted of thick deposits of silt. Almost no SAV was found growing here but large amounts of detached *Zostera* and *Ruppia* was observed, apparently washed in from adjacent areas. Scattered *Ruppia* was observed growing on the offshore bar at depths near MLW. On the Bay side of the bar however, only *Zostera* occurred. The bottom here consisted of fine sands and, as with transect A to the north, the *Zostera* ended at a relatively shallow depth of -4.6 dm.

Vaucluse Shores (Franktown quadrangle)

The Vaucluse Shores area consisted of a large, triangular-shaped bed of SAV which was 700 m across at its widest point and over 3500 m in length. The system is protected from strong west and northwest winds and long fetch of the Chesapeake Bay by a series of broad, well defined offshore bars. Review of historical photographs (see Historical Analysis-Vaucluse Shore) indicated that these intertidal bars were moving in a north-south direction along the shoreline in conjunction with the movement of large sand spits. The northern half of the bed was actually a fairly recent phenomenon (<20 years) and was formed as one of the more northern bars migrated south. The bars protecting the southern half of the beds, possibly controlled by tidal movements through the Hungar's Creek inlet, have remained relatively stable over the last 40 years.

The distribution of SAV within the Vaucluse Shores site has been sampled with seven transects (A1,A,B,C,D,E,F). Figure 25 illustrates the locations of these transects across the SAV bed. Zones of similar vegetational composition as determined from the transects are also outlined. The profiles of these transects are presented in three figures 26a, b and c.

As with the other areas of SAV previously described around the lower Bay, *Zostera* and *Ruppia* dominated this site. A zone of *Ruppia* and *Zannichellia palustris* was, however, noted at transect F. As described

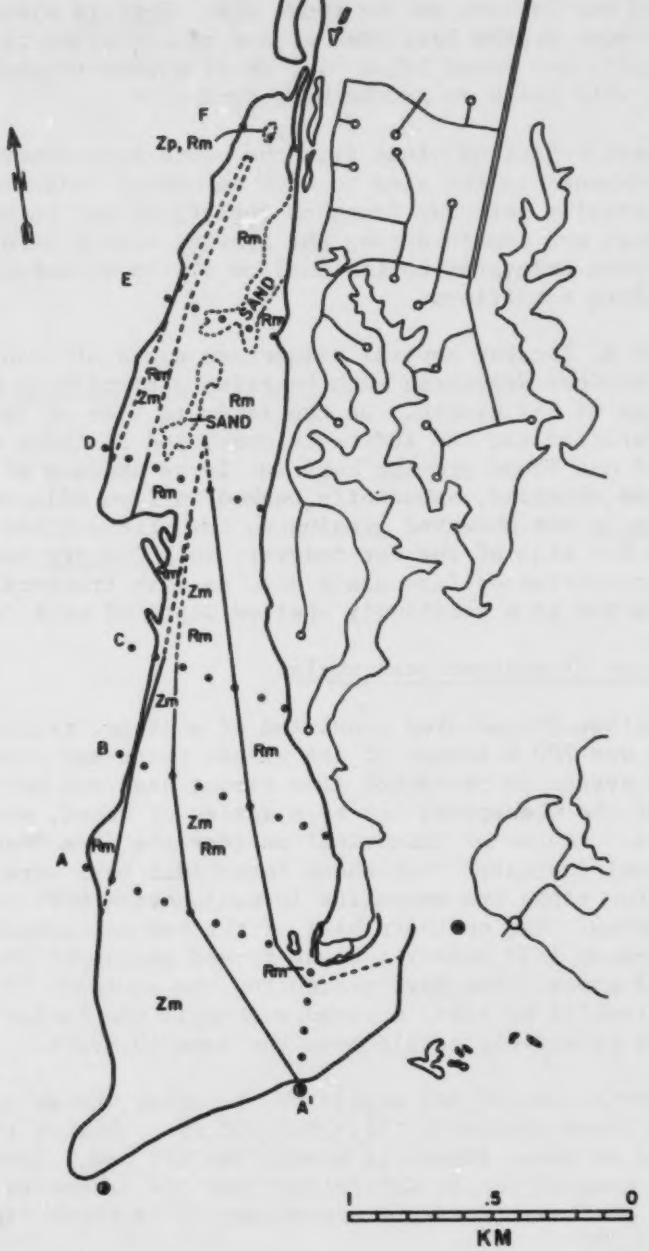

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Figure 25. Delineation of SAV bed, zones of similar vegetation and position of transects at Vaucluse Shores area.

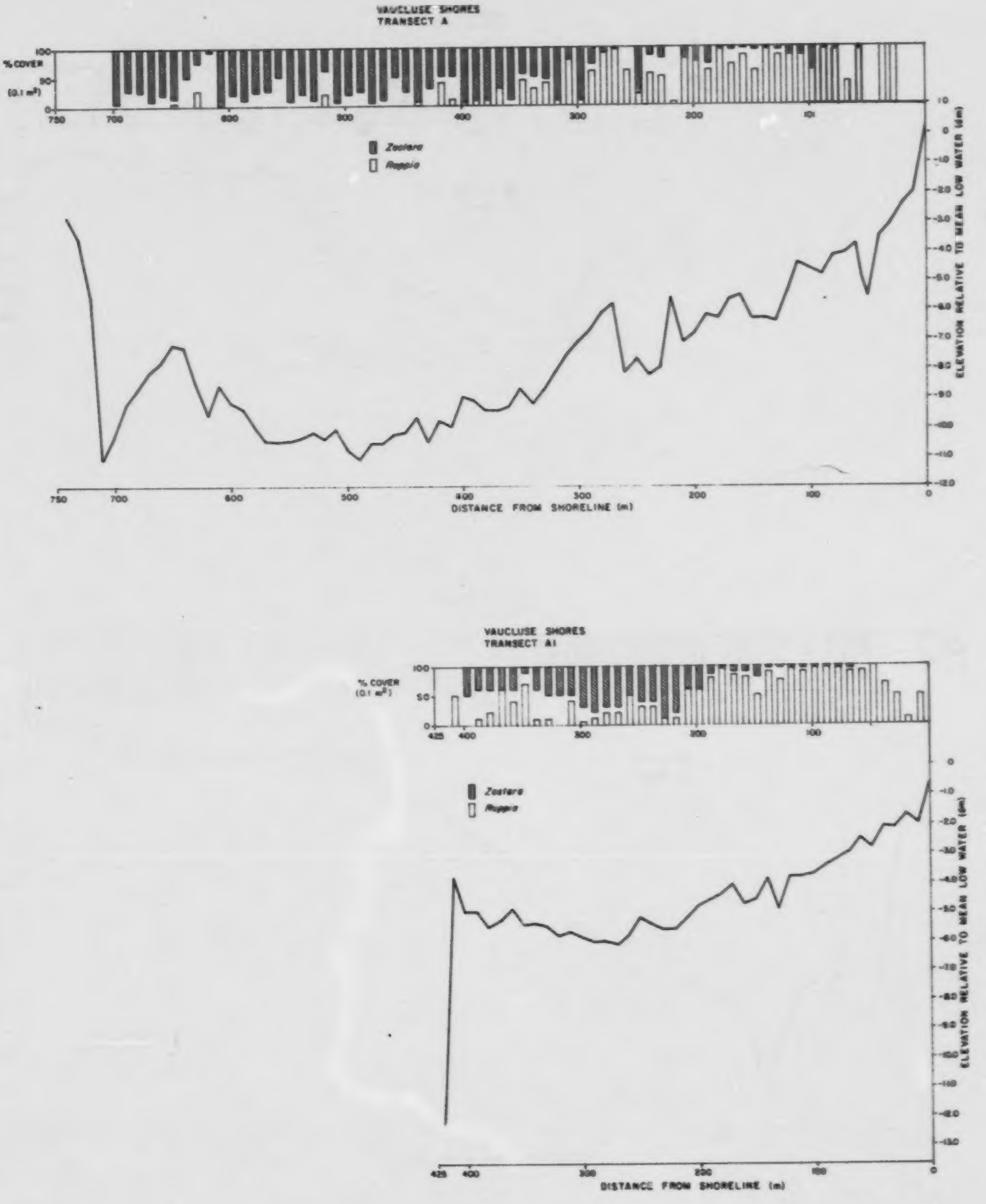
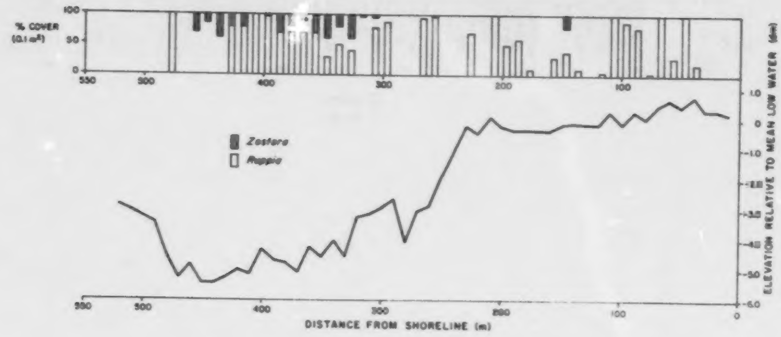


Figure 26. Depth profiles and percent cover estimates for Zostera and Ruppia at Vaucluse Shores transects.


VAUCLUSE SHORES
TRANSECT C

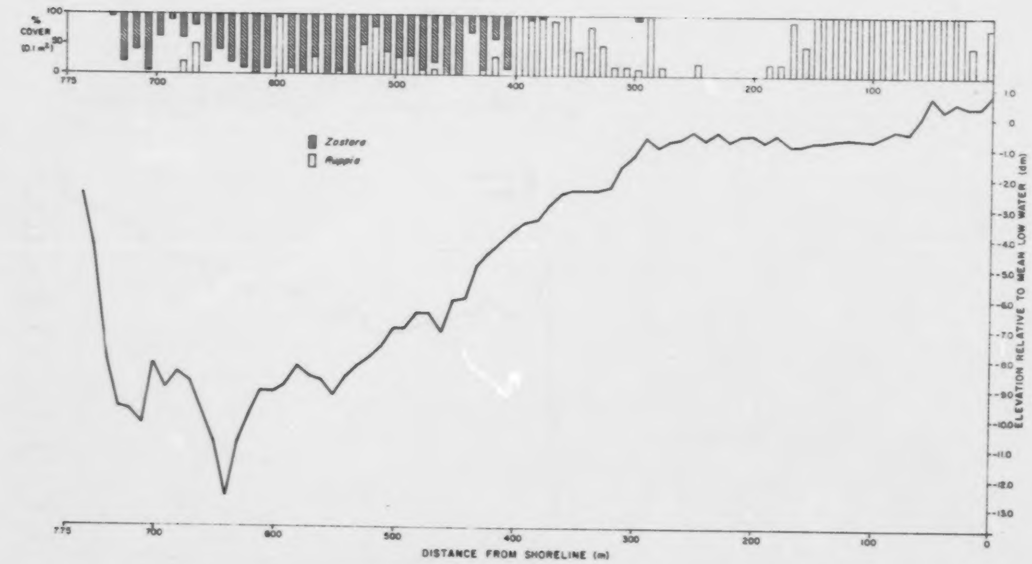

VAUCLUSE SHORES
TRANSECT B

Figure 26. (Continued)

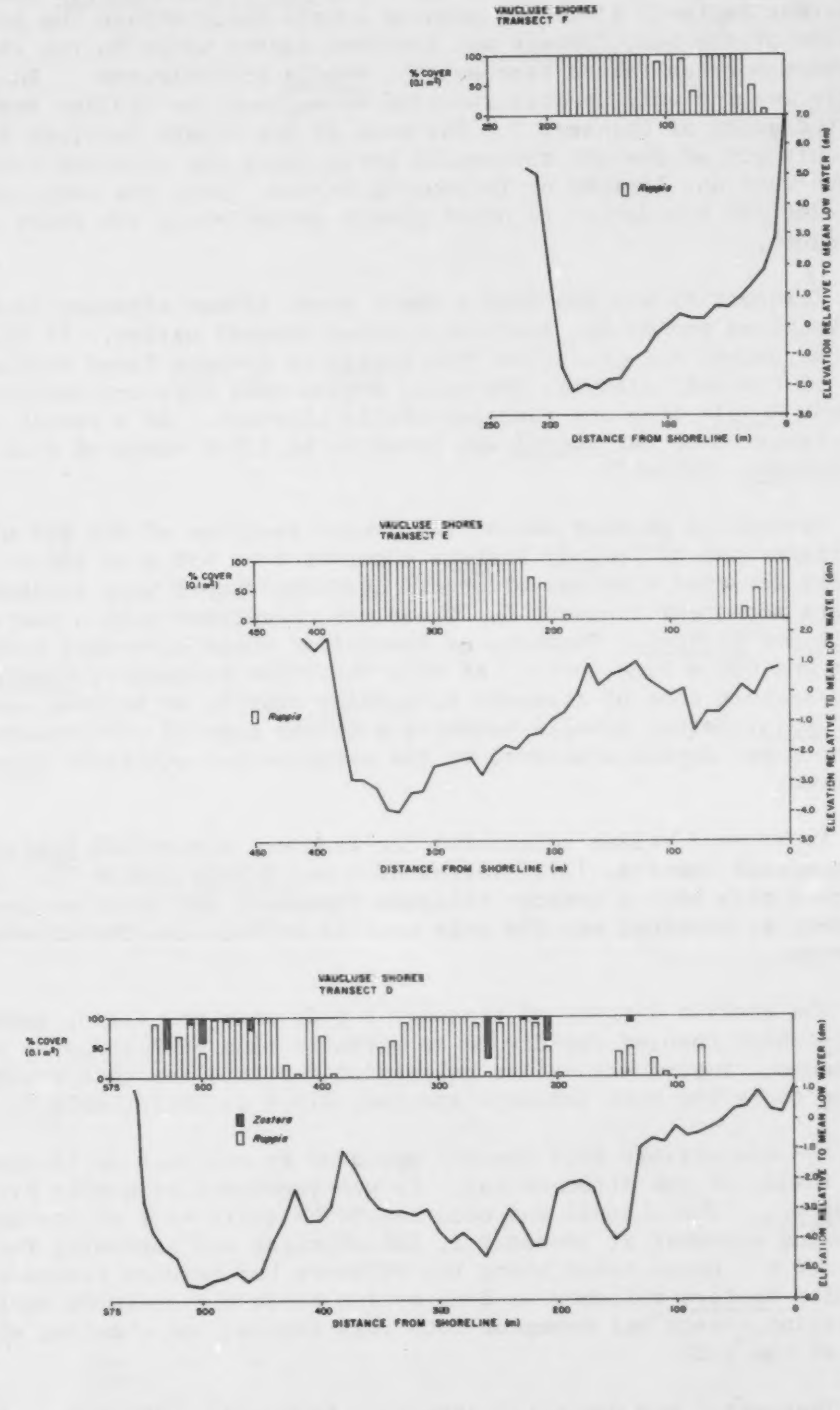


Figure 26. (Continued)

previously and illustrated in Figure 19, Zostera and Ruppia dominated at different depths. Since the greater depths occur within the southern portion of the bed, Zostera was dominant there; while in the shallow, northern portion (above transect D), Ruppia predominated. In addition, Ruppia was the only species recorded throughout the shallow inshore areas located south of transect D. For most of its length Vaucluse Shores was the only one of the six transected areas where the offshore limits of plant growth were not limited by increasing depths. Here the sand bars acted as well-defined boundaries to plant growth except along the inlet channel to the south.

Transect A1 was run from a small marsh island adjacent to the tip of the Vaucluse peninsula, south to a fixed channel marker. It illustrates to some extent the gradation from Ruppia to Zostera found throughout the rest of the bed, although the water depths here were not sufficient to exclude Ruppia from any portions of the transect. As a result the importance value for Ruppia was found to be 119.6 compared with only 80.4 for Zostera (Table 7).

Transect A crossed one of the deeper sections of the bed with a resultant zone of largely Zostera observed from 450 m to 700 m. Aerial imagery revealed a series of short, crescent-shaped bars located in the Zostera zone near transect A. These were vegetated with a mixture of Ruppia and Zostera. Portions of several of these bars were indicated at 520 m and 630 m from shore. As with the other transects, Ruppia dominated the nearshore zone of transect A, grading next to an interim zone of Zostera and Ruppia, before finally becoming a deeper zone of predominately Zostera. As the water depths shallowed on the offshore bar scattered Ruppia was observed.

Importance values calculated for transect A revealed Zostera to be the dominant species, 119.6 versus 80.3 for Ruppia (Table 7). Zostera occurred with both a greater relative frequency and relative cover. Transect A, however, was the only profile at Vaucluse Shores where this occurred.

The profile diagram of transect B indicates the broad, inshore zone of Ruppia which changed rapidly to an offshore zone of Zostera as depths increased. Importance values calculated for this transect again revealed Ruppia to be the more dominant species, 113.7 to 86.2 (Table 7).

A comparatively deep channel appeared to run in a north-south direction just inside of the offshore bar. It was vegetated primarily by dense stands of Zostera. The channel was observed to be quite wide at transect A, narrowing somewhat at transect B, and shoaling and narrowing further at transect C. Cores taken along the offshore bar between transect B and C revealed Zostera rhizomes as deep as 1 m below the sediment surface indicating recent bar movement into this channel and shoaling within this part of the bed.

Transect C was dominated primarily by Ruppia. It is here that recent changes have been observed in species dominance from Zostera to Ruppia. As mentioned above, the area was possibly in response to shoaling due to bar movement.

Transects D, E, and F illustrate the habitat found in the northern portion of the Vaucluse Shores site. Here Ruppia predominated as bottom depths rarely exceeded -5.0 dm. Zannichellia was observed throughout a small area crossed by transect F. Although it was not found in any of the other transected areas, it is widely distributed species in the Bay and is tolerant of mesohaline waters.

A relic bar, which used to form the northern limit of the SAV bed, was observed to come ashore just north of transect E. It can be seen in the profiles at approximately 360 m along transect D and 150 m along transect E. A small channel was observed between this bar and the larger bar which now forms the offshore limits of the bed. Zostera was observed throughout this channel as it continued north some distance above transect E. Evidence again indicated that this entire upper portion of the Vaucluse Shores bed was rapidly shoaling due to the southward bar and spit migration. Eventually, it should become too shoal even for Ruppia to exist, thus illustrating the dynamic nature of the SAV beds found along this eastern shoreline of the Bay.

DISTRIBUTION OF SAV ALONG VIRGINIA'S TIDAL SHORELINE

Virginia is endowed with over 5300 km (3,300 miles) of tidal shoreline in which much of the adjacent littoral zone has the potential for supporting submerged aquatic vegetation. As described previously, this shoreline can be divided into two regions. The first consists of the mesohaline and polyhaline areas of the Chesapeake Bay and its major tributaries (James, York, Rappahannock, Potomac, etc.). The second includes the oligohaline and freshwater portions of the major tributaries. Historically, the first region with its Zostera and Ruppia beds has received the greatest attention since it has been found in this study to have SAV covering over 8400 hectares (20,750 acres) of shallow bottom in densities ranging from very sparce (<1 per m^2) to very dense (>1000 m^2). These areas are of extremely high value to the coastal ecosystem and their locations and relative densities have been described previously in this report.

However, continuum exists between these higher salinity areas (15-25 $^o/oo$) and the tidal, freshwater areas of the major rivers. Figure 4 and Appendix C present the data obtained from the field sampling along this continuum. Time did not permit an exhaustive field survey of all portions of Virginia's tidal rivers and Bay shoreline but enough data were obtained from selected areas to provide a description of the distribution and abundance of SAV's throughout tidal Virginia.

Species Associations

Table 8 lists a total of 20 species of submerged aquatics and their percent occurrence at the 93 locations which contained vegetation. Since

TABLE 8. PERCENT OCCURRENCE OF SAV SPECIES AT 93 STATIONS THROUGHOUT TIDAL VIRGINIA

Species	Percent Occurrence
Zannichellia palustris	42
Ceratophyllum demersum	35
Najas minor	23
Vallisneria americana	13
Elodea canadensis	13
Nitella sp.	12
Najas quadalupensis	12
Zostera marina	12
Ruppia maritima	12
Potamogeton pectinatus	6
Callitriche verna	6
Potamogeton perfoliatus	6
Potamogeton cripus	5
Myriophyllum spicatum	3
Potamogeton filiformis	3
Chara	2
Najas flexilis	2
Elodea nuttallii	1
Potamogeton nodosus	1
Potamogeton foliosus	1

this was not a random sampling of locations along Virginia's shoreline, it cannot be considered truly representative of the relative abundance of each particular species throughout Virginia. Certainly *Zostera* and *Ruppia* would have to be considered the overwhelmingly dominant species found in Virginia's tidal waters. They are nearly the only species found in the mesohaline and polyhaline regions (except for *Zannichellia*) and form extensive beds many thousands of m^2 in size. However, except for an occasional area of *Ruppia*, they are not found where salinities are consistently below 10 ppt (VIMS, Data Base). For the purposes of minimizing redundance only those areas of *Zostera* and *Ruppia* where transects were made are included in Appendix C. All other locations where *Zostera* and *Ruppia* were found are marked on the appropriate topographic sheets included in Appendix B. It is apparent from this study as well as previous work (Orth, 1976, 1977b) that *Zostera* and *Ruppia* both co-occur in varying amounts in nearly all the mesohaline and polyhaline grass beds.

A dendogram of plant species associations calculated for the data in Appendix B is presented in Figure 27. This inverse, hierarchical classification (Boesch, 1977) shows three primary plant associations: A, B, and C. (Table 9), with *Callitriche verna* associated with both B and C.

TABLE 9. ASSOCIATIONS OF SAV IN VIRGINIA'S TIDAL WATERS

A	B	C
Zostera marina	*Potamogeton crispus*	*Najas minor*
Ruppia maritima	*Potamogeton perfoliatus*	*Najas quadalupensis*
	Potamogeton pectinatus	*Ceratophyllum demersum*
	Vallisneria americana	*Elodea canadensis*
	Zannichellia palustris	*Nitella*
	Callitriche verna	*Callitriche verna*
	*Chara**	*Potamogeton foliosus**
	*Myriophyllum spicatum**	*Najas flexilis**
		*Potamogeton filiformis**
		*Potamogeton nodosus**
		*Elodea nuttalli**

*Less than 5 percent occurrence.

Those species which occurred in less than five percent of the field survey stations were omitted from the calculations. However, for completeness they have been reintroduced to the appropriate associations based on the locations of the few stations where they occurred and other nearby associated submerged vegetation.

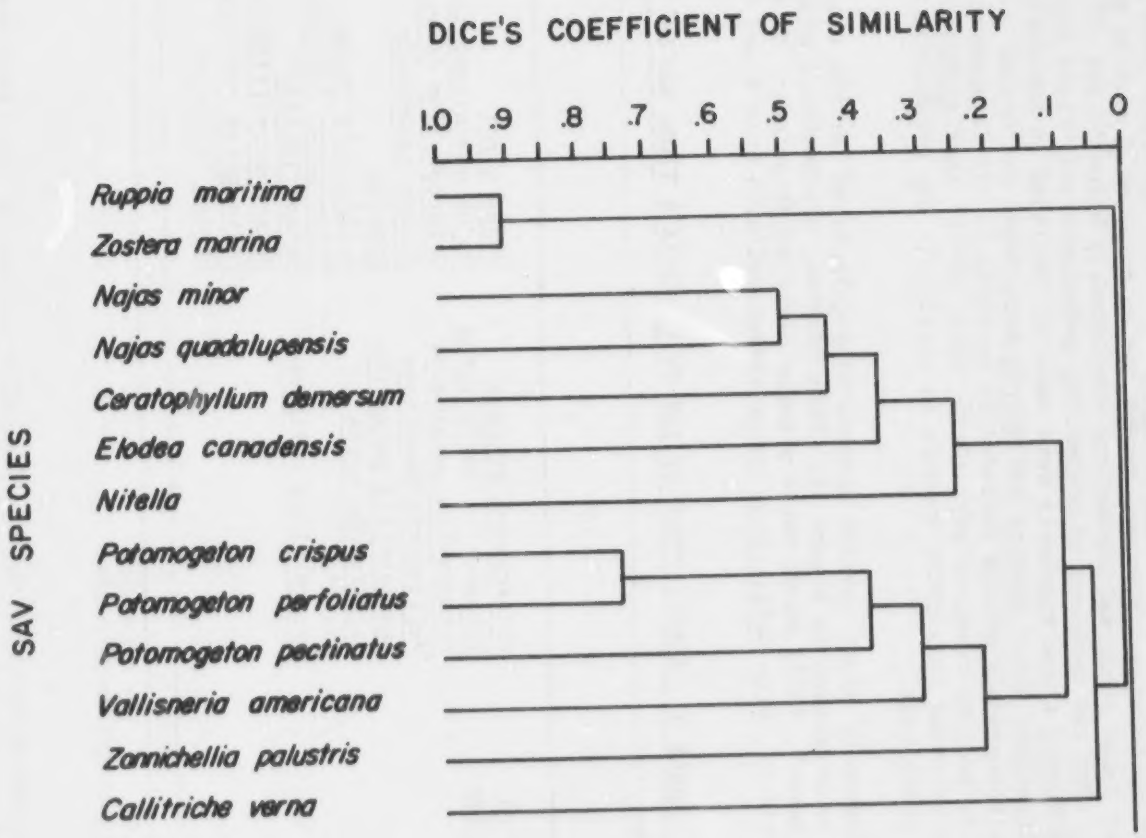


Figure 27. Dendrogram of SAV species associations in the lower Chesapeake Bay and its tributaries.

These three plant species assocations may best be explained by their locations and the salinity tolerance of each of the species. Species association A, composed of Zostera and Ruppia, is tolerant of the highest salinities found in the Bay, and therefore, they are found dispersed along the lower Bay shoreline as well as the lower portions of the major rivers.

It is interesting to note that although Ruppia is much more tolerant of freshwater than Zostera (Stevenson and Confer, 1978), it is not found to any significant extent in Virginia rivers upstream from those areas where it co-occurs with Zostera. Kerwin (1966) reported finding Ruppia in the Poropotank River, a tributary of the York River located approximately 14 km above the most upstream areas where large Zostera and Ruppia beds have been recorded (i.e. Claybank). Surveys of the Poropotank conducted for this study revealed no Ruppia, although numerous other species (Ceratophyllum demersum, Potamogeton pectinatus, etc.) were found (Appendix C).

Species association B listed in Table 9 includes those species common in waters where salinities are generally 15 ppt or less. In Virginia these species have been found to occur in varying amounts in each of the major rivers, however, the largest beds occur along the Potomac River in the vicinity of Upper Machodoc Creek. In the other rivers these species tend to occur only in small pocket areas at the head of numerous marsh guts where they are generally not distinguishable from the air.

Zanichellia is generally more widespread than any of the other species in this group and occurs further downstream in areas of higher salinity. Although it grows mixed with the others in the group it also occurs in monospecific stands at the heads of many small creeks.

Vallisneria americana is found in greatest abundance along the Potomac River, especially in the vicinity of the Rt. 301 bridge (See Mathias Point Topographic Sheet, Appendix). It is also found in small amounts in each of the other rivers and occurs both above and below the upper limits of saltwater intrusion. Potamogeton perfoliatus, P. pectinatus and P. crispus are also most abundant along the Potomac River in the vicinity of Upper Machodoc Creek. Although appropriate salinity regimes (5-10 ppt) are found in each of the other major rivers, suitable shoal areas for the formation of large SAV beds are not present. Callitriche verna is another species which is found in the narrow transition zone between fresh and brackish water. It was observed at the heads of the Poropotank River adjacent to large areas of Taxodium distichum dominated swamps and at the heads several creeks along both the Rappahannock and Potomac River.

Association C includes those species that are commonly found in freshwater areas. The decrease in the salinity tolerance from association A to B to C has resulted in an increase in diversity, with association C having the greatest species richness. Ceratophyllum demersum appears to be the most common, as it occurred at 35 percent of the sampling stations. It was generally observed floating throughout the heads of many freshwater creeks and in many areas formed dense stands especially along the Chickahominy River. Najas minor was also common throughout the Chickahominy

River as was Najas quadalupensis. N. minor was also observed along the Rappahannock River.

Species Distribution

The distribution of the 20 species of submerged vegetation found in this study have been described to some extent in the preceeding section and have been mapped and discussed in other sections of this report. It was felt by the authors, however, that a summary of how these species were distributed along Virginia's tidal rivers and Bay shoreline would be of value. Therefore the following section describes segments of Virginia's shoreline and the vegetation that was documented to occur or was most likely to occur there.

The upper portion of Virginia's side of the Potomac River, from the Chain Bridge in Washington, D.C. to Mathias Point Neck, contained few areas of SAV. Although little field work was conducted here during this study, aerial reconnaissance combined with previous field investigations in this region have failed to reveal any significant areas of SAV. However, based on the dominant marsh vegetation (i.e. Nuphar, Peltandra, Pontederia) found in the numerous creeks along this section of the river, small areas of Ceratophyllum demersum, Vallisneria americana and Najas are likely to exist, especially at the creek heads and in small marsh guts.

From Mathias Neck Point to Mattox Creek numerous areas of SAV were present. These included species such as Zannichellia palustris, Potamogeton crispus, Potamogeton perfoliatus and Vallisneria americana which were found along the shoreline of the lower portions of the major creeks. Scattered Zannichellia was common at the heads of these creeks, especially Upper Machodoc, Rosier, Monroe and Mattox. Myriophyllum spicatum occurred in isolated areas but had its densest concentration at the head of Rosier Creek.

From Mattox Creek downstream to Smith Point at the mouth of the Potomac few SAV existed. The absence of SAV along this section of the Potomac may be due to its greater degree of wave exposure which could preclude the development of SAV. The creeks, which had suitable habitat, were also lacking in submerged vegetation. Zannichellia and Ceratophyllum demersum were recorded at the head of Nomini Creek while Zannichellia and Myriophyllum were found at the head of Lower Machodoc Creek, but in neither area did they occur in significant quantities. Other creeks downstream from these two, such as the Yeocomico River, were generally devoid of submerged vegetation. It would not be unusual, however, especially in early summer, to find scattered small amounts of Zannichellia at the heads of these creeks. Large beds of SAV located at the mouth of the Coan River were observed in historical aerial photographs. Because of the high salinities in this region, they were probably composed of a mixture of Zostera marina and Ruppia maritima. They have not been present since at least 1971, however.

The section of Chesapeake Bay shoreline between Smith Point at the mouth of the Potomac River and Windmill Point at the mouth of the Rappahannock River was vegetated with numerous beds of Zostera and Ruppia. These have been mapped and described previously in this report. The numerous creeks found along this region (e.g. the Wicomico River) contained beds of *Zostera* and *Ruppia* along their lower portions. They may also have contained scattered *Zannichellia* near their heads, although none were observed in this study.

The Rappahannock River had a species distribution similar to that of the Potomac River, a progression form head to mouth of associations C to B to A (Table 9).

Although little field work was conducted in the most upstream tidal portions of the Rappahannock (above Rt. 301 bridge), scattered *Ceratophyllum* is likely to be found there associated with the areas of freshwater marsh and tidal swamp. *Ceratophyllum* was observed south of the bridge at the head of Elmwood Creek. From here downstream to Tappahannock no SAV were observed along the Rappahannock River shoreline. Several of the larger creeks, such as Cat Point, Mount Landing and Piscataway, did contain dense beds of SAV at their heads. Included were such species as *Ceratophyllum*, *Najas*, *Callitriche verna* and *Vallisneria americana*. Downstream portions of these and other creeks in this region contained scattered *Zannichellia*.

Large beds of SAV at one time (prior to 1971) extended as far upstream along the Rappahannock River shoreline as the town of Moratico. These were vegetated with *Zostera* and *Ruppia*. However by 1978, most of this shoreline was completely unvegetated.

Zannichellia was present along this region but only within the small tributary creeks, especially at their heads where salinities were reduced. Priest (personal communication) reported *Zannichellia* found at most of the heads of the small creeks from this middle region of the river downstream to the Rappahannock River's mouth. The only *Zostera* and *Ruppia* beds observed within the river system were sparce areas occurred near the mouth of the Corrotoman River.

The shoreline between the Rappahannock and York Rivers contained extensive beds of *Zostera* and *Ruppia*, especially in the region of Mobjack Bay. These have been mapped and described previously. The Piankatank River did contain submerged vegetation at its head in contrast to the other creeks in this region. Here species tolerant of oligohaline and freshwater conditions occurred. They included *Nitella*, *Callitriche*, *Najas*, *Ceratophyllum* and *Elodea*. *Callitriche* continued upstream from the Piankatank into an area of tidal swamp known as Dragon Run. *Nitella* formed scattered dense pockets in shallow areas just downstream from the swamp, while the other species formed small fringes or pocket areas associated with the adjacent marsh vegetation. In the middle reaches of the Piankatank *Zannichellia* was observed (Priest, personal communication) while at the near of the river's mouth scattered sparce beds of *Zostera* and *Ruppia* were found.

The York River contained extensive areas of oligohaline and freshwater marshes and swamps along its two tributaries, the Mattaponi and Pamunkey Rivers. However, large amounts of organic matter were present in these waters, and as such, the areas appeared unsuitable for SAV. *Ceratophyllum*, which is tolerant of low light conditions, was the most common species found associated with these wetland areas, but it was widely scattered and in sparse amounts.

Downstream from the confluence of the Mattaponi and Pamunkey Rivers, at West Point, to the town of Gloucester Point, no SAV was found along the York River shoreline. Several of the larger creeks along this section (e.g. Ware Creek, Poropotank River) did, however, contain small, dense beds of submerged vegetation at their heads. Here numerous low salinity and freshwater grasses occurred including Ceratophyllum, Elodea, Nitella, Vallisneria, etc. Downstream portions of these and other creeks, where salinities were higher, contained Zannichellia but in sparse amounts.

From Gloucester Point and Yorktown, downstream to the mouth of the York River, scattered beds dominated by Zostera and Ruppia occurred. The small creeks along this section of the river were generally devoid of vegetation in their upstream portions. The region from the mouth of the York River south to New Point Comfort at the mouth of the James River contained extensive beds of Zostera and Ruppia which have been mapped and described previously in this report. The two large creeks found along this region, the Poquoson and Back Rivers, have Zostera and Ruppia near their mouths, but little submerged vegetation within the creeks themselves.

The upper James River contained extensive areas of tidal freshwater marsh and swamp from the Chickahominy River upstream to its fall line in Richmond. Although no field work was conducted in this region during this study, aerial reconnaissance combined with previous field investigations here have failed to reveal significant areas of SAV. It would not be unlikely to find scattered Ceratophyllum, as well as other freshwater species associated with these wetland areas, however.

The submerged vegetation found within a portion of the Chickahominy River, a major tributary of the James, has been described in detail earlier in this report. Generally, it consisted of fringe and pocket areas of Ceratophyllum and Najas associated with the adjacent Peltandra dominated wetlands. Although only a portion of the Chickahominy was mapped for this report, the remainder of the river system contained a similar distribution of SAV species.

From the Chickahominy River downstream to the mouth of the James River few SAV species were found. Several of the creeks along this region contained submerged vegetation in very sparse amounts. Ceratophyllum was recorded at the head of Grays Creek, while Zannichellia was found in Skiffes Creek, Mill Creek and the Warwick River. In no place did they occur in more than trace amounts.

The submerged vegetation found along Virginia's eastern shore has been mapped and described previously in this report. The SAV consisted of large beds of very sparce to very dense areas of Ruppia and Zostera located at the mouths of the numerous creeks found along this region, as well as adjacent to the necks of land separating these creeks. The greatest concentrations of SAV were found in the vicinity of Hungar's and Cherrystone

Creeks. The Vaucluse Shore area located at Hungar's Creek has been described in detail earlier. Other creeks further north along this shoreline contained large areas of SAV but in much reduced densities. No SAV was observed at the heads of these creek systems, although it would not be unlikely if scattered *Zannichellia* did occur.

Along the Maryland-Virginia border little SAV occurred in the vicinity of the Pocomoke River. Further west in the shoal areas behind several of the Bay islands including Tangier and Great Fox, large beds of SAV were found. Here, as along the rest of the eastern shoreline of Virginia *Zostera* and *Ruppia* predominated.

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APPENDIX A

GENERAL GUIDELINES FOR MISSION PLANNING AND EXECUTION FOR OBTAINING AERIAL PHOTOGRAPHY OF SAV

1. Tidal Stage - Imagery will be acquired at low tide, ± 1.5 feet, as predicted by the National Ocean Survey (NOS) tables. Record tidal stage.

2. Plant Growth - Imagery will be acquired when growth stages ensures maximum delineation of SAV, and when phenologic stage overlap is greatest. Record plant growth stage (dormant, juvenile, mature, etc.).

3. Sun Angle - Imagery will be acquired when surface reflection from sun glint does not cover more than 30% of frame. Sun angle should generally be between 20° and 40° to minimize water surface glitter. At least 60% line overlap and 30% side lap will be used to minimize image degradation due to sun glint. Record sun angle and time of day of imagery acquisition.

4. Turbidity - Imagery will be acquired when clarity of water ensures complete delineation of grass beds. Record water turbidity conditions.

5. Wind - Imagery will be acquired during periods of no or low wind (no maximums have been established). Off-shore winds are preferred over on-shore winds if wind conditions cannot be avoided. Record wind speed and direction.

6. Atmospherics - Imagery will be acquired during periods of no or low haze and/or clouds below aircraft. There should be no more than scattered or thin broken clouds, or thin overcast above aircraft, to ensure maximum SAV to bottom contrast. Record cloud cover and haze conditions.

7. Sensor Operation - Imagery acquired will be vertical with less than 5 degrees tilt. Scale/altitude/film/focal length combination will permit resolution and identification of one square meter area of SAV (surface). Record film/filter/camera/focal length combination and imagery scale.

8. Plotting - Each flight line will include sufficient identifiable land area to assure accurate plotting of grass beds. Record compass direction and aircraft speed and altitude.

APPENDIX B

TOPOGRAPHIC QUADRANGLES SHOWING THE DISTRIBUTION AND ABUNDANCE OF SAV

(1 = <10%; 2 = 10-40%; 3 = 40-70%; 4 = 70-100%)

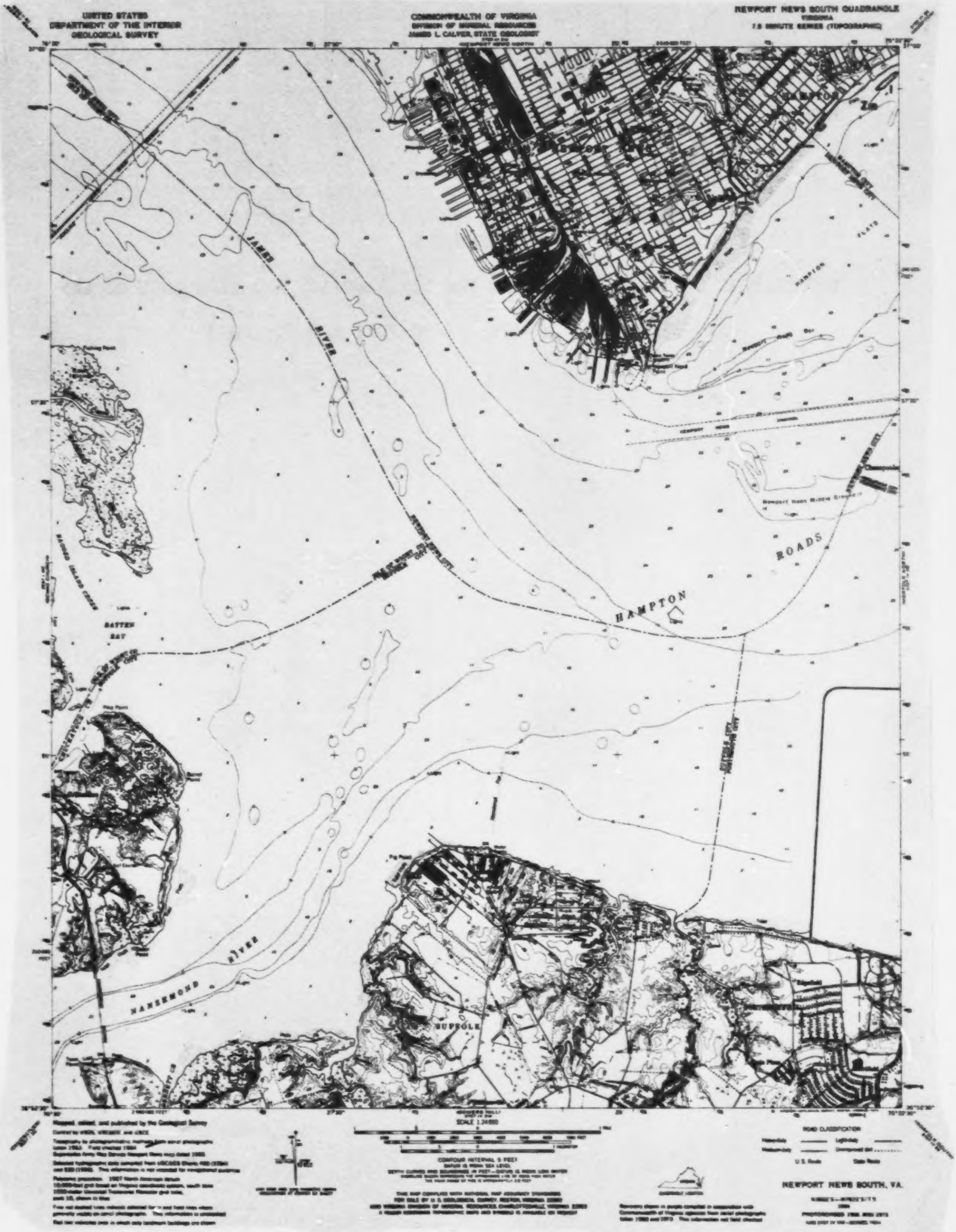
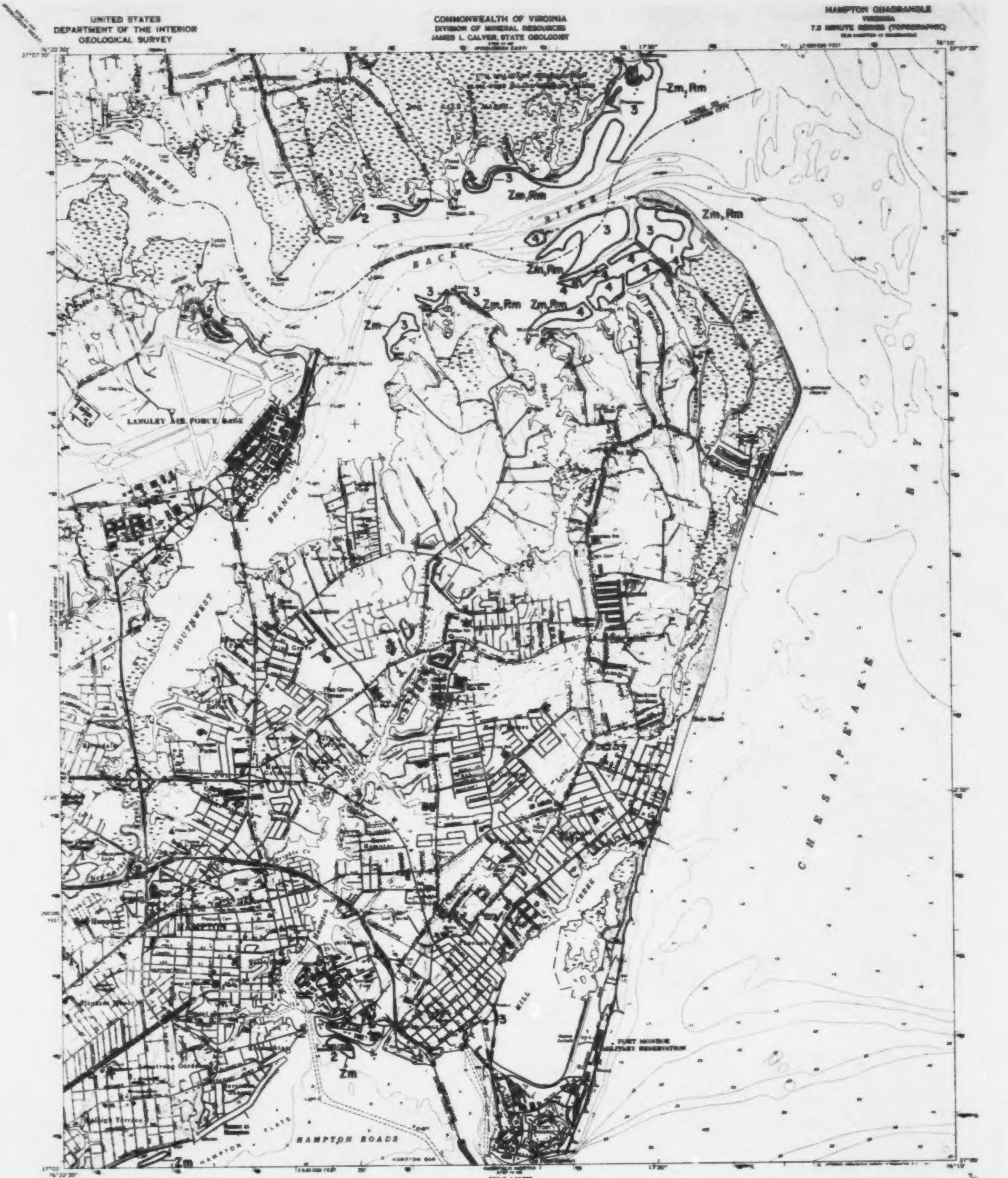

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
NEWPORT NEWS SOUTH QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
JAMES
RIVER
HAMPTON
ROADS
BATTEN
BAY
NANSEMOND
RIVER
SUFFOLK
HAMPTON
FLATS
ROAD CLASSIFICATION
U.S. Route
State Route
CONTOUR INTERVAL 5 FEET
NEWPORT NEWS SOUTH, VA.

Figure B-1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COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
HAMPTON QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
Zm, Rm
3
2
4
Zm
NORTHWEST BRANCH
BACK RIVER
LANGLEY AIR FORCE BASE
SOUTHWEST BRANCH
CHESAPEAKE BAY
HAMPTON
FORT MONROE MILITARY RESERVATION
HAMPTON FLATS
HAMPTON ROADS
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
HAMPTON, VA.

Figure B-2

Reproduced from best available copy.

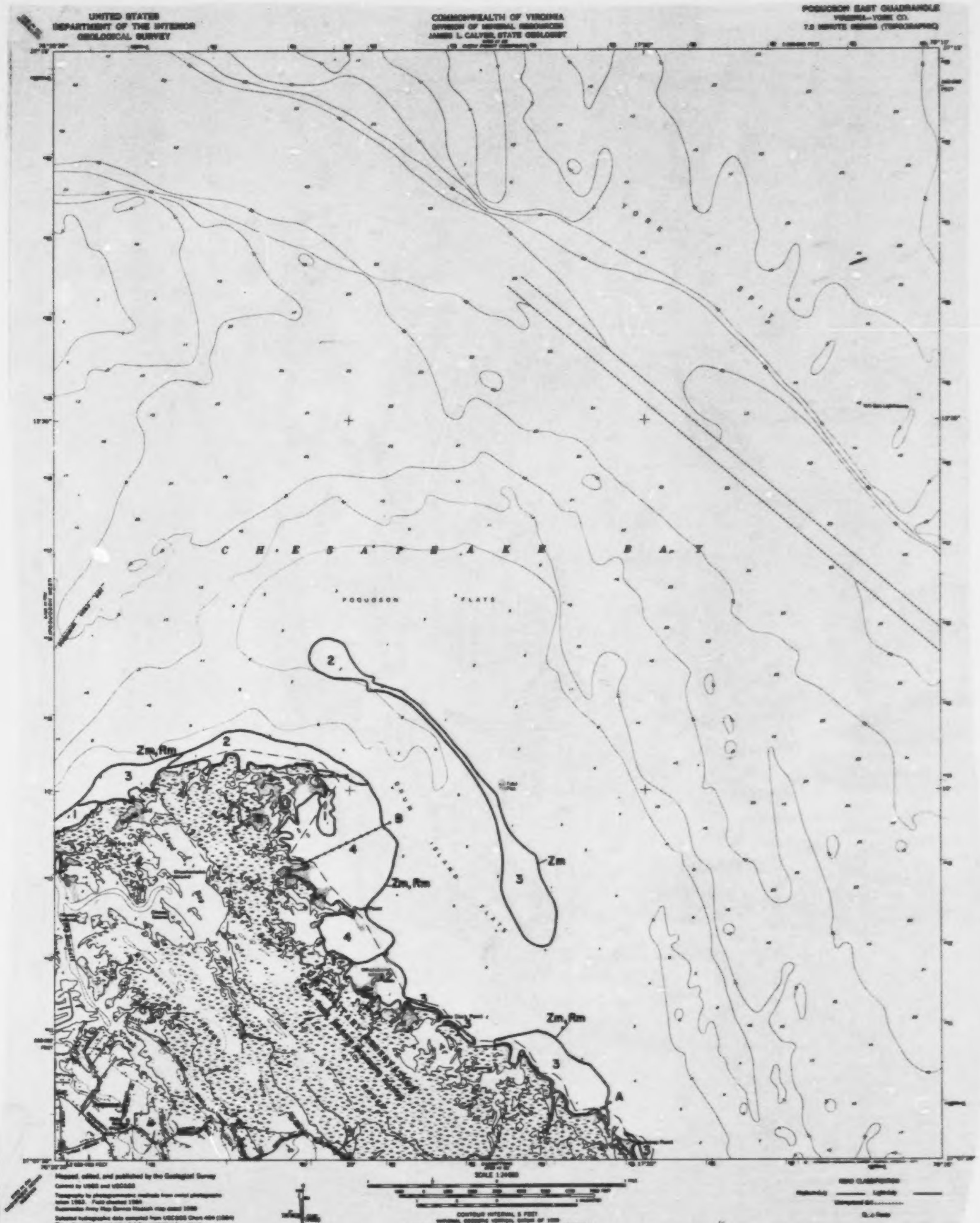
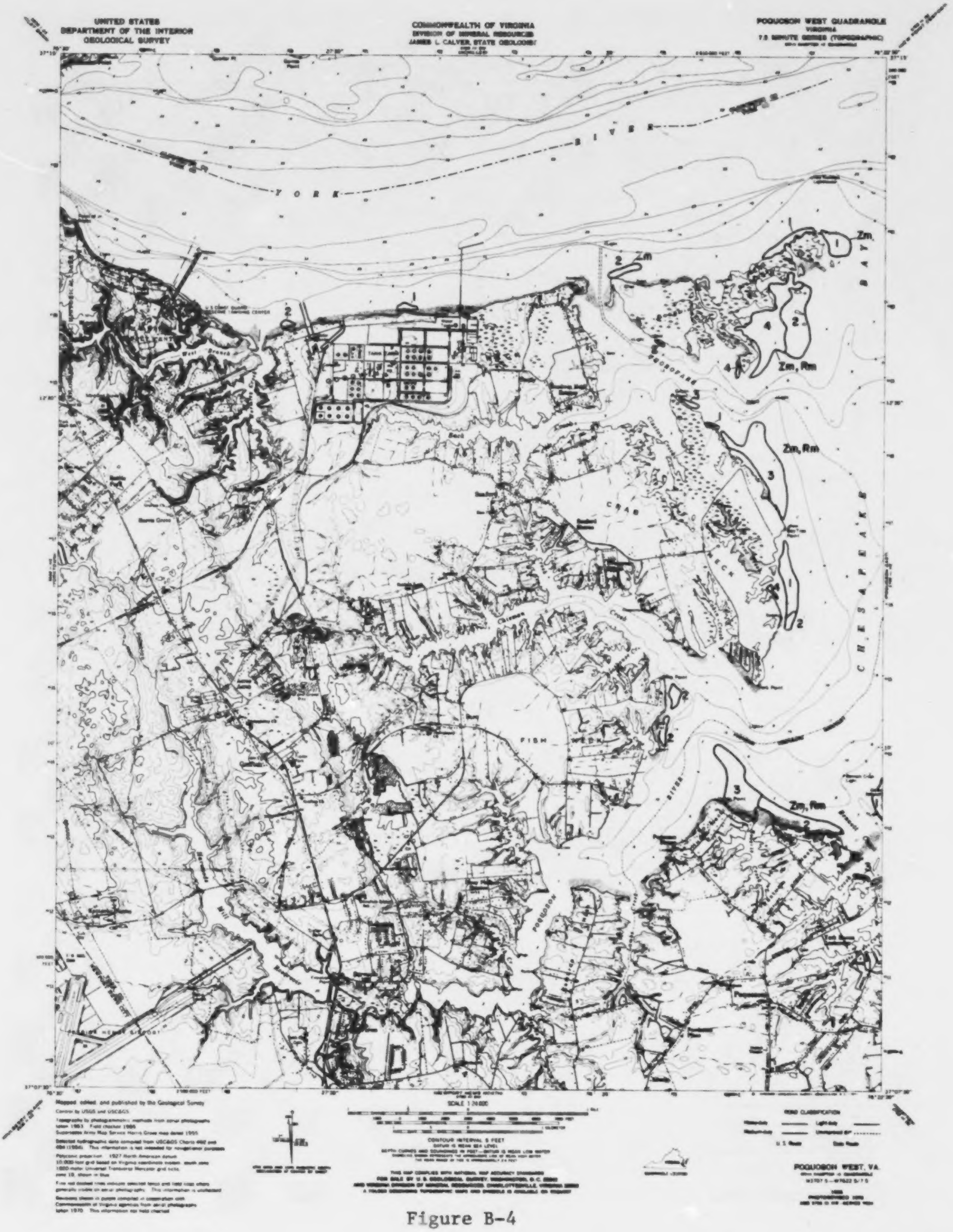

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
POQUOSON EAST QUADRANGLE
VIRGINIA–YORK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
YORK SPIT
CHESAPEAKE BAY
POQUOSON FLATS
2
Zm,Rm
2
3
B
4
Zm,Rm
Zm
3
4
3
Zm,Rm
3
A
POQUOSON EAST, VA.

Figure B-3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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
POQUOSON WEST QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
YORK RIVER
CHESAPEAKE BAY
CRAB NECK
FISH NECK
POQUOSON RIVER
Zm
Zm, Rm
1
2
3
4
Mapped, edited, and published by the Geological Survey
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
Light-duty
Unimproved dirt
U. S. Route
State Route
POQUOSON WEST, VA.

Figure B-4

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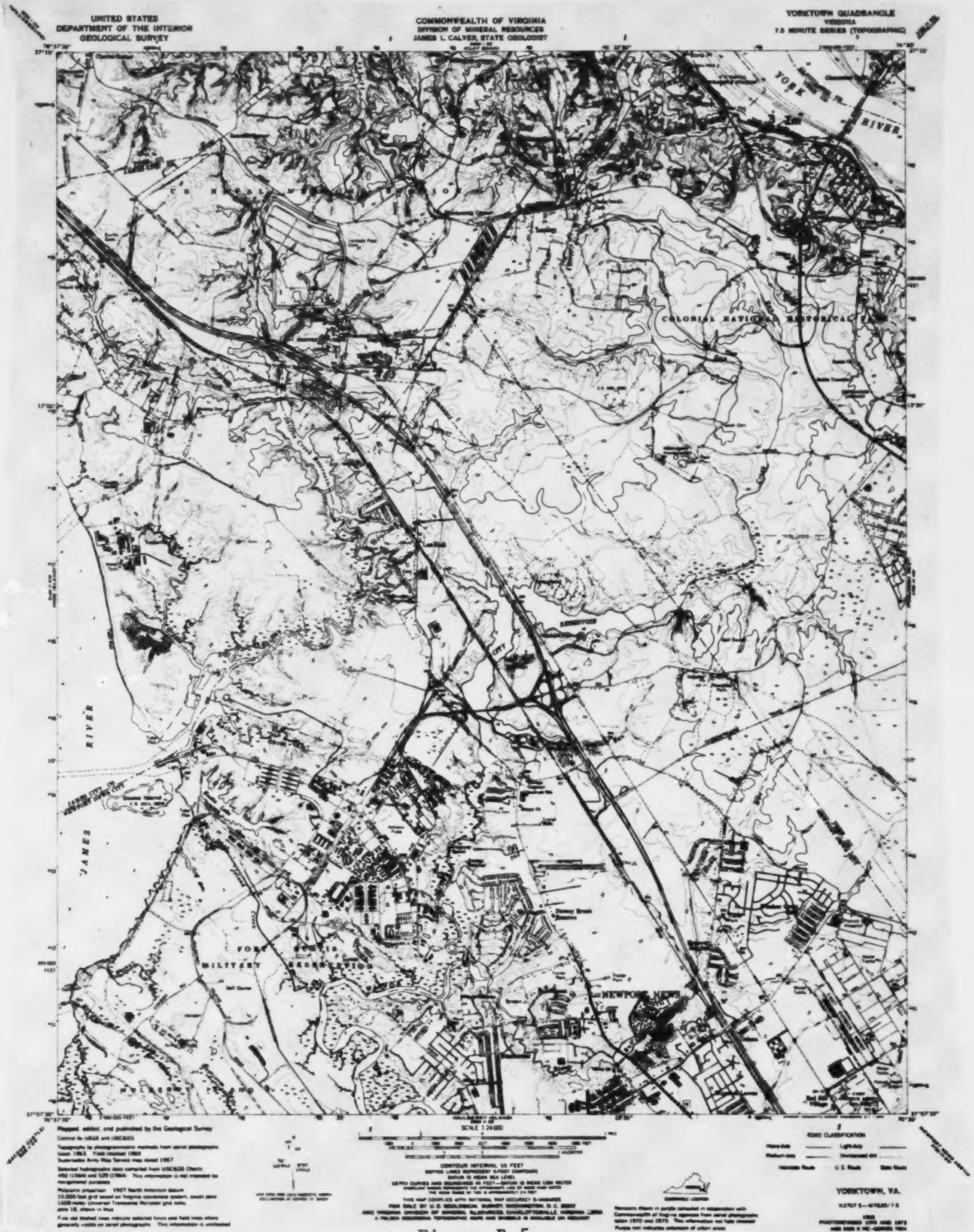
UNITED STATES
DEPARTMENT OF THE INTERIOR
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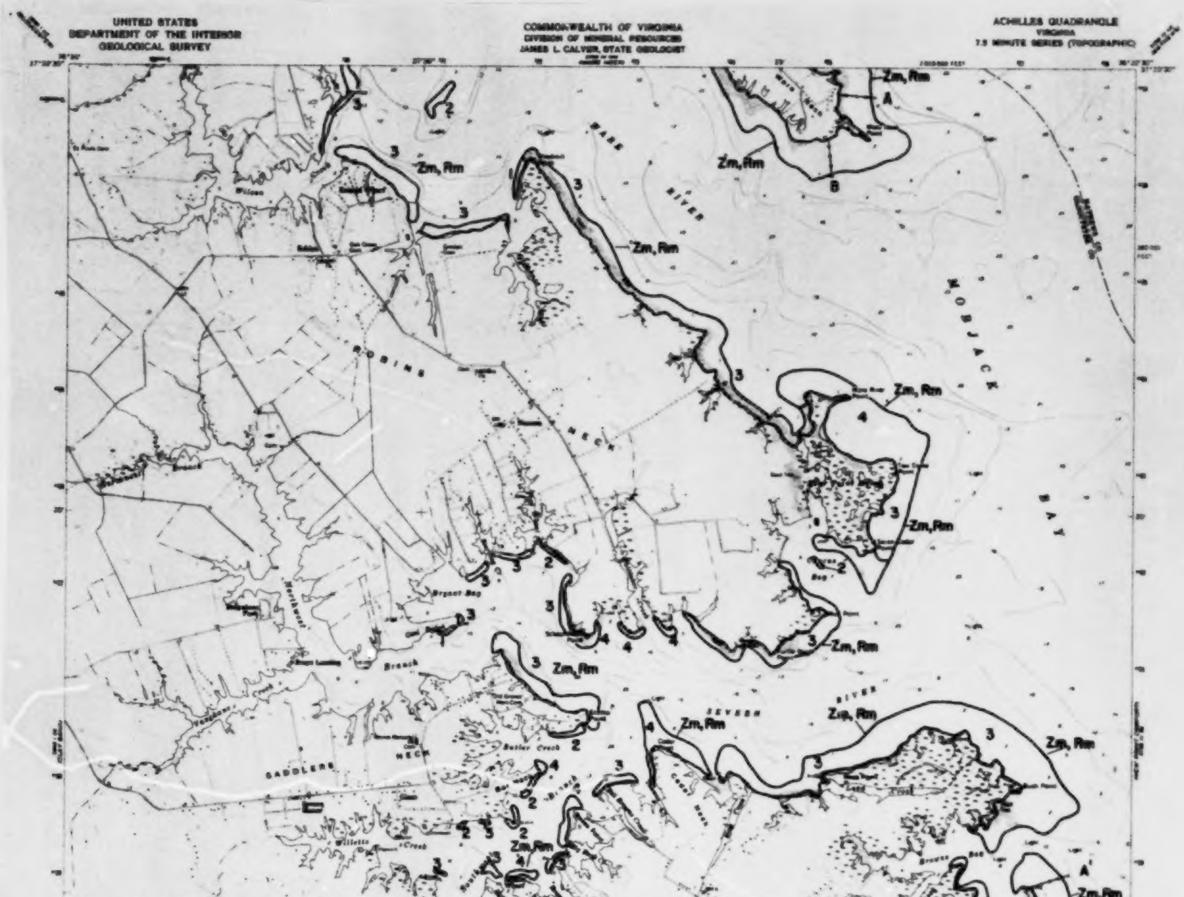
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
YORKTOWN QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
YORK RIVER
COLONIAL NATIONAL HISTORICAL PARK
JAMES RIVER
FORT EUSTIS MILITARY RESERVATION
NEWPORT NEWS
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
YORKTOWN, VA.

Figure B-5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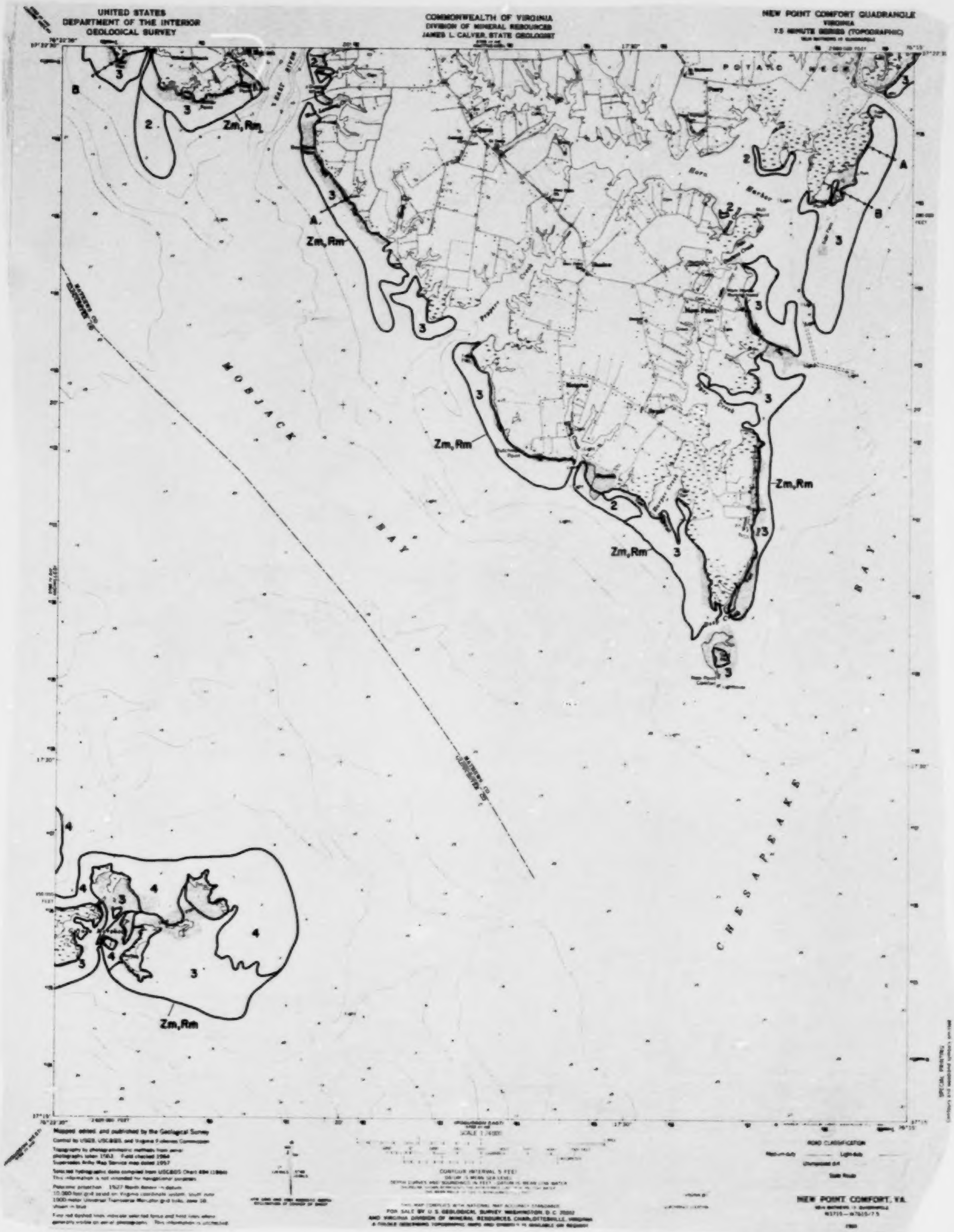
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
ACHILLES QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
Zm, Rm
A
B
A'
B'
1
2
3
4
WARE RIVER
MOBJACK BAY
ROBINS NECK
SEVERN RIVER
SADDLERS NECK
YORK RIVER
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
ACHILLES, VA.

Figure B-6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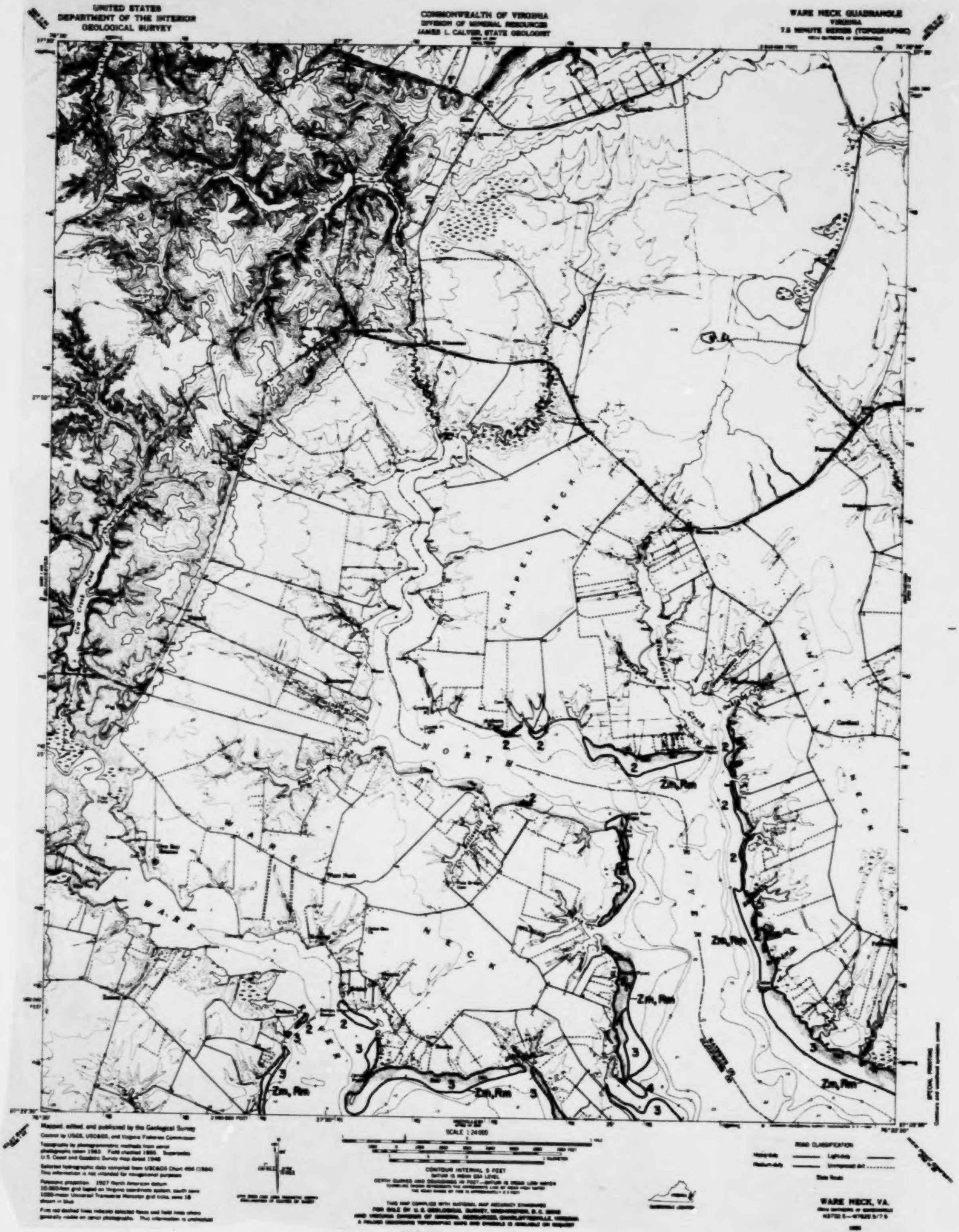
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
NEW POINT COMFORT QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
POTATO NECK
MOBJACK BAY
CHESAPEAKE BAY
A
B
2
3
4
Zm,Rm
ROAD CLASSIFICATION
NEW POINT COMFORT, VA.
CONTOUR INTERVAL 5 FEET

Figure B-7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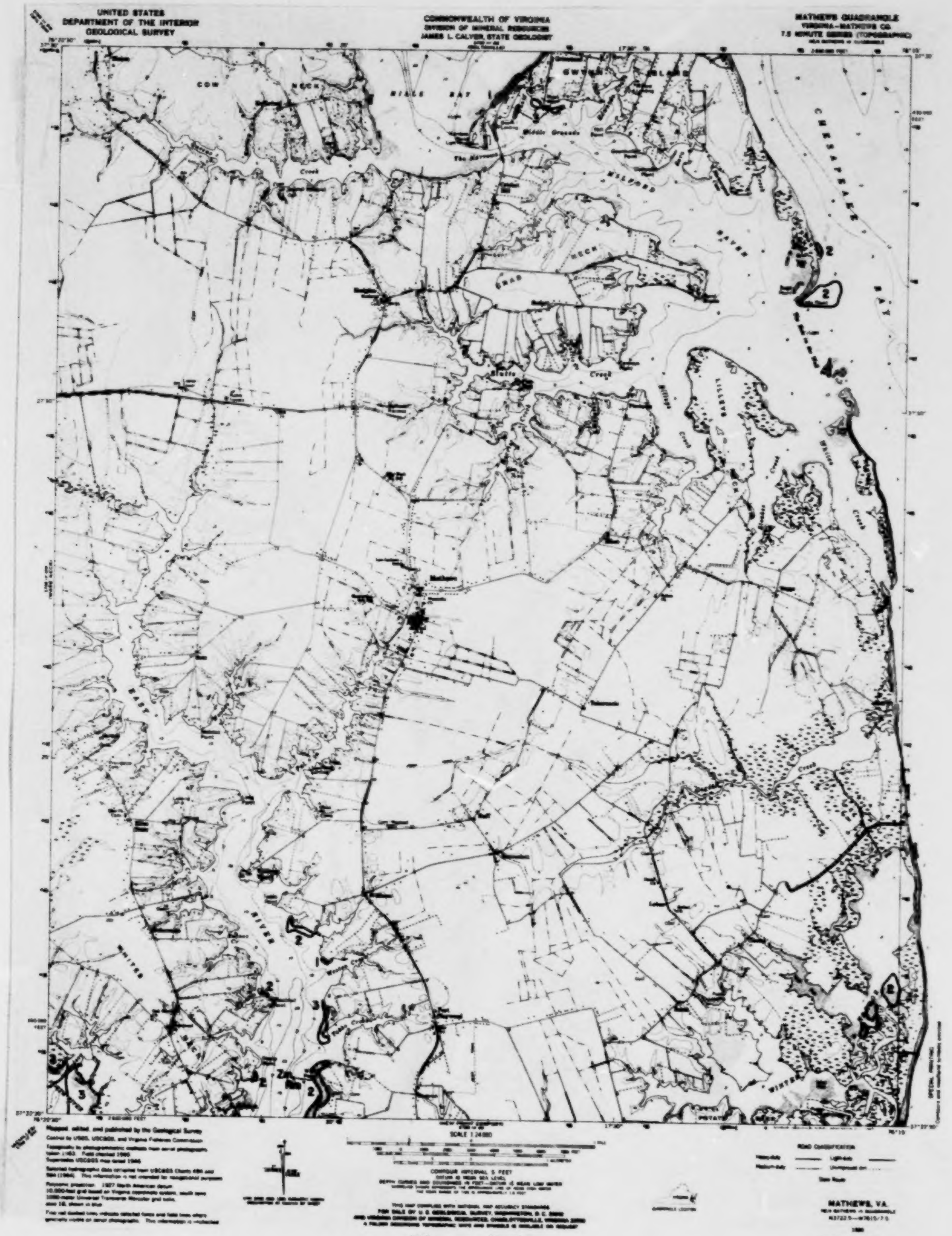
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
WARE NECK QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
CHAPEL NECK
NORTH
WARE NECK
2
3
Zm, Rm
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
ROAD CLASSIFICATION
WARE NECK, VA.

Figure B-8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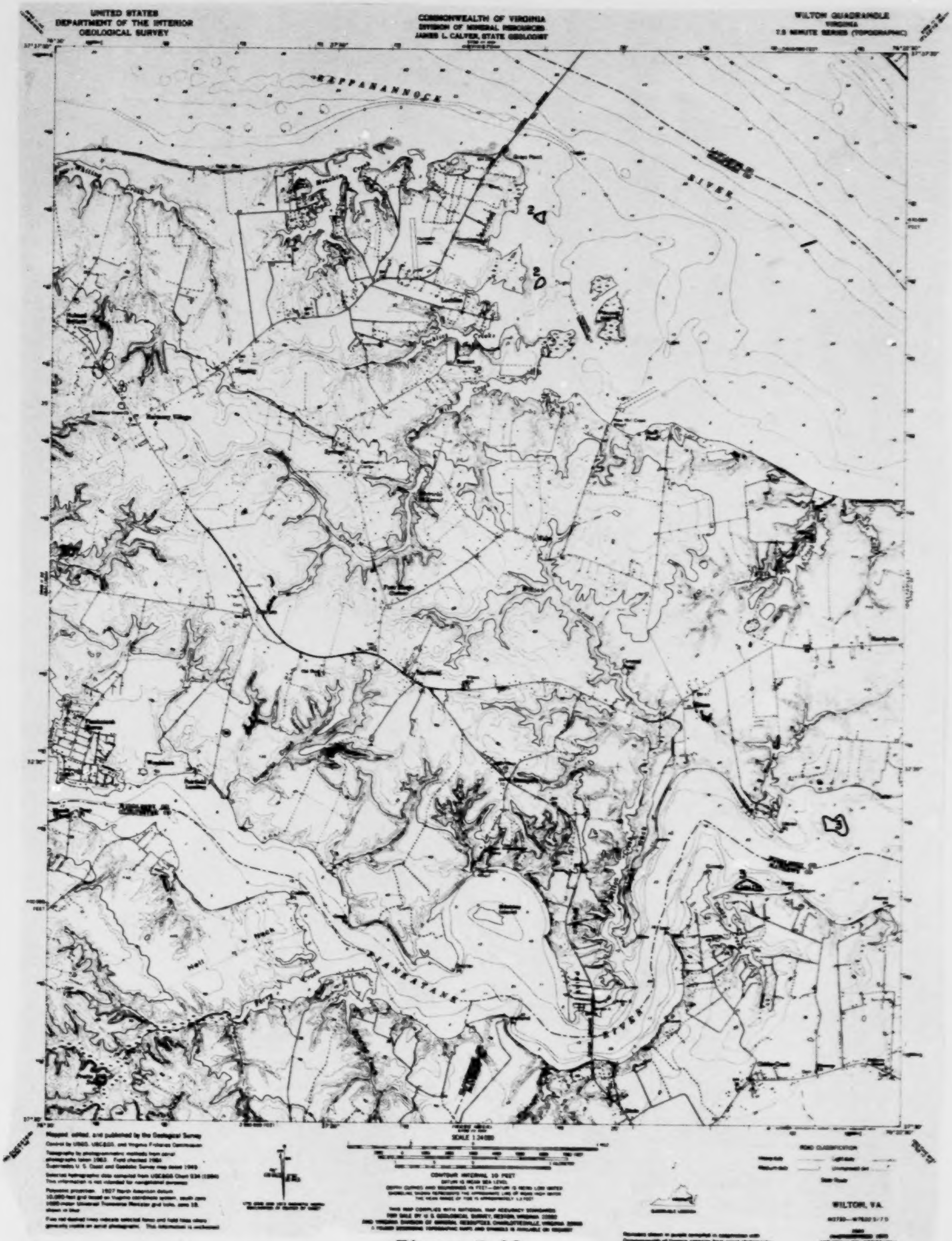
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
MATHEWS QUADRANGLE
VIRGINIA–MATHEWS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
COW NECK
HILLE BAY
GWYNN ISLAND
CHESAPEAKE BAY
MILFORD HAVEN
Mathews
2
3
CONTOUR INTERVAL 5 FEET
SCALE 1:24000
MATHEWS, VA.

Figure B-9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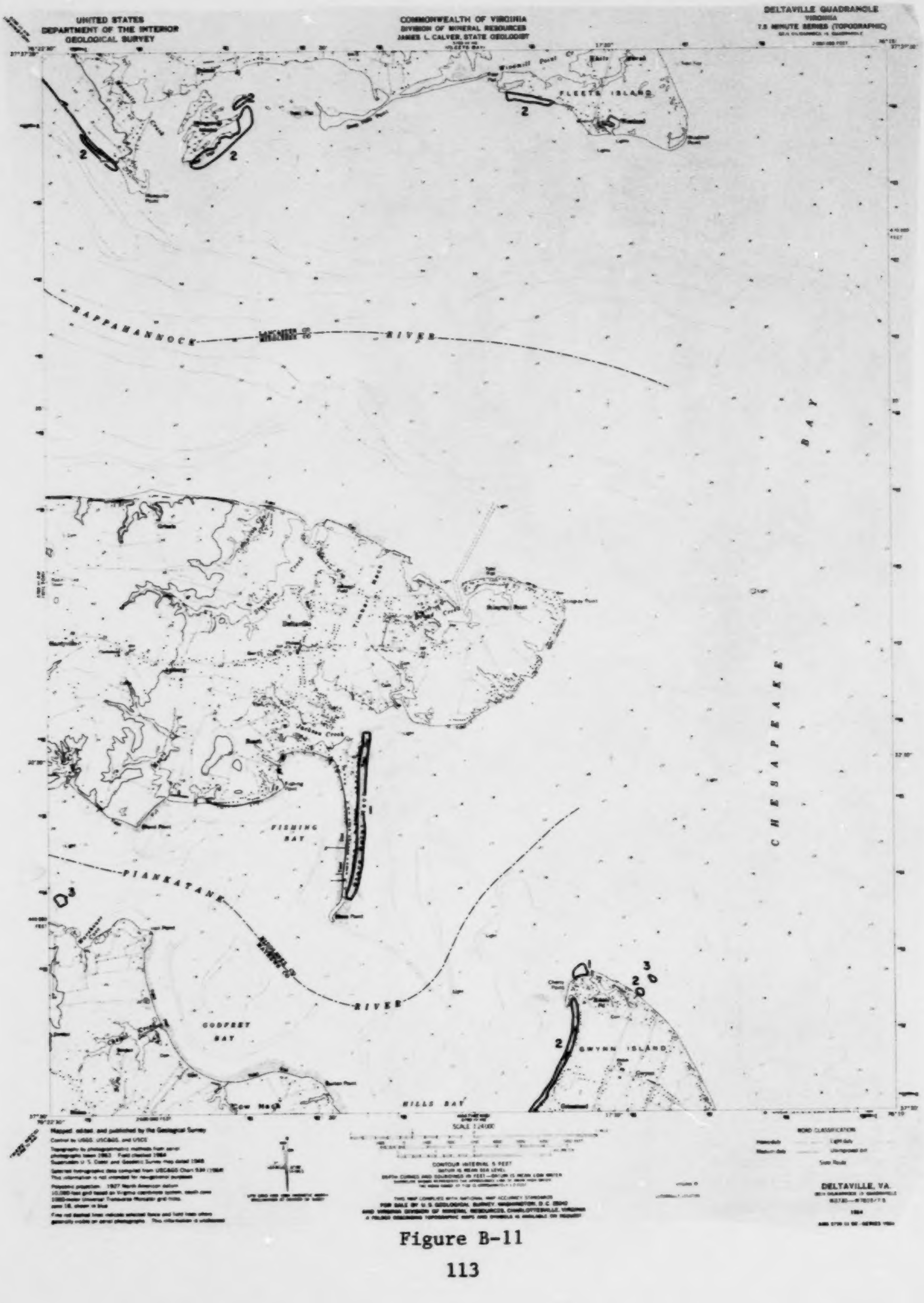
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
WILTON QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
RAPPAHANNOCK
RIVER
PIANKATANK
RIVER
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
WILTON, VA.

Figure B-10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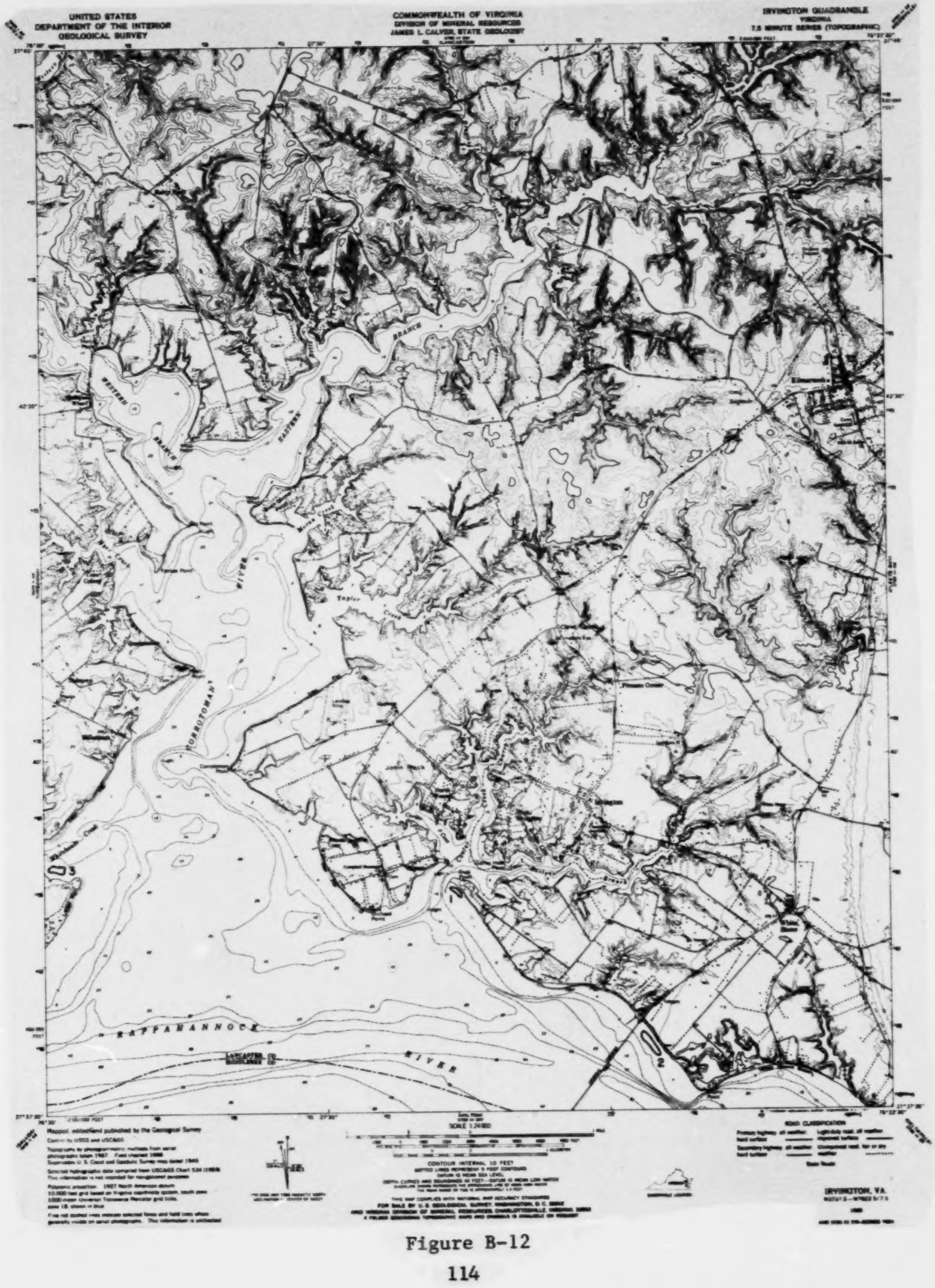
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
DELTAVILLE QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
FLEETS ISLAND
2
2
2
RAPPAHANNOCK
RIVER
BAY
CHESAPEAKE
FISHING BAY
1
3
PIANKATANK
RIVER
1
3
2
2
GODFREY BAY
GWYNN ISLAND
HILLS BAY
Cow Neck
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
DELTAVILLE, VA.

Figure B-11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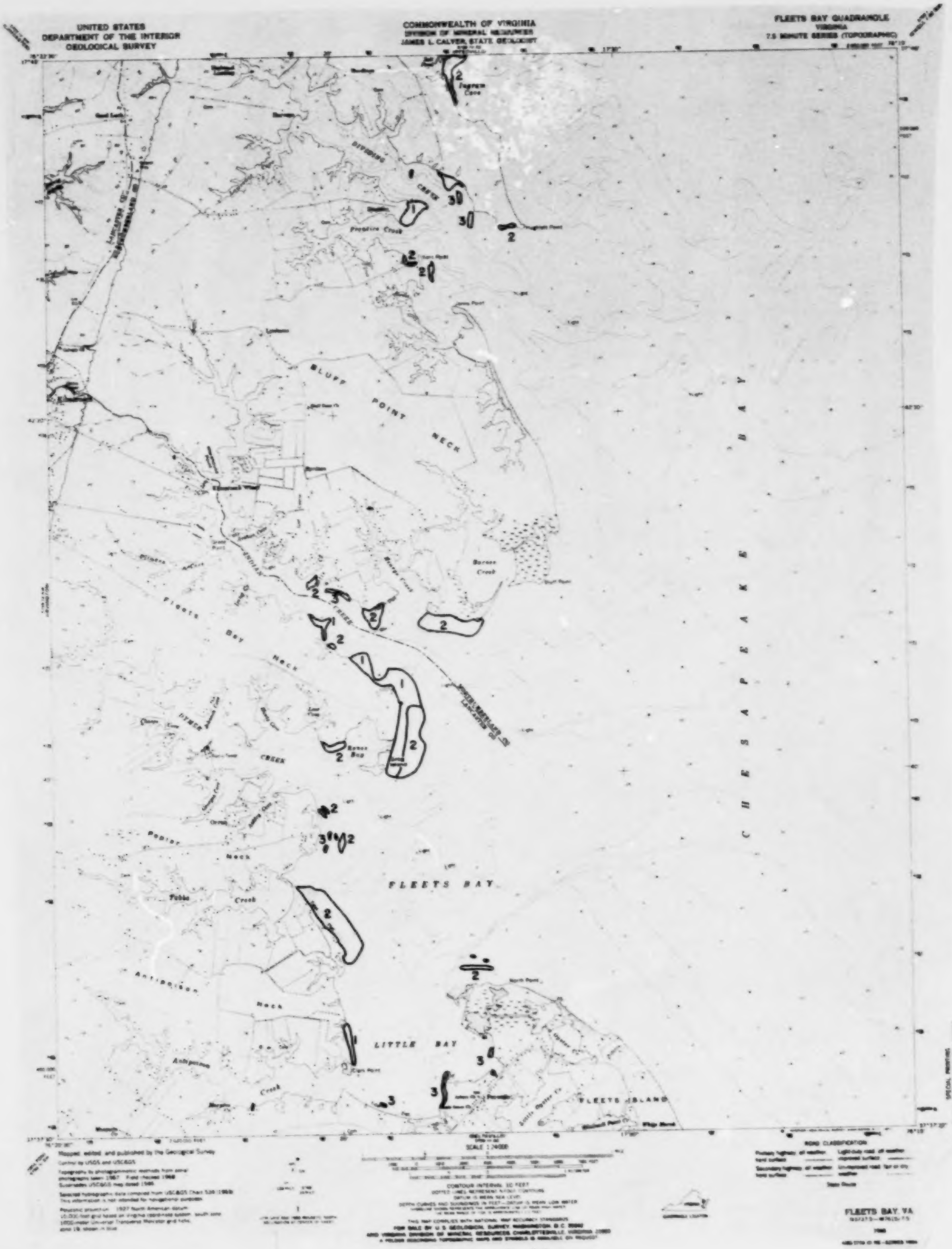
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
IRVINGTON QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
CORROTOMAN
RIVER
Taylor Creek
RAPPAHANNOCK
RIVER
1
2
3
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
ROAD CLASSIFICATION
IRVINGTON, VA.

Figure B-12


UNITED STATES
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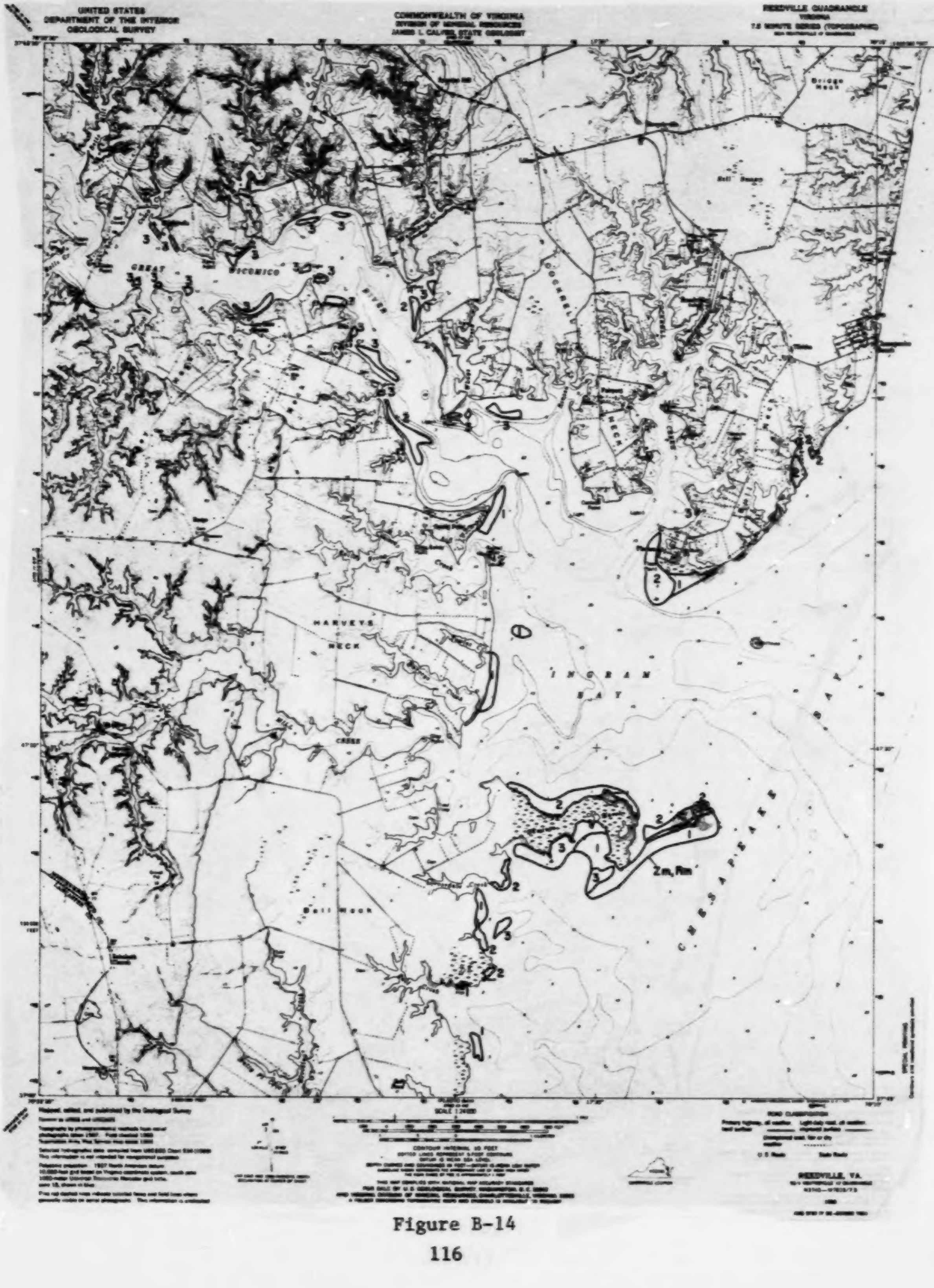
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
FLEETS BAY QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
Ingram Cove
Dividing Creek
Prentice Creek
BLUFF POINT NECK
Barnes Creek
Fleets Bay Neck
Dymer Creek
Poplar Neck
Tabbs Creek
FLEETS BAY
Antipoison Neck
Antipoison Creek
LITTLE BAY
FLEETS ISLAND
CHESAPEAKE BAY
1
2
3
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
FLEETS BAY, VA.

Figure B-13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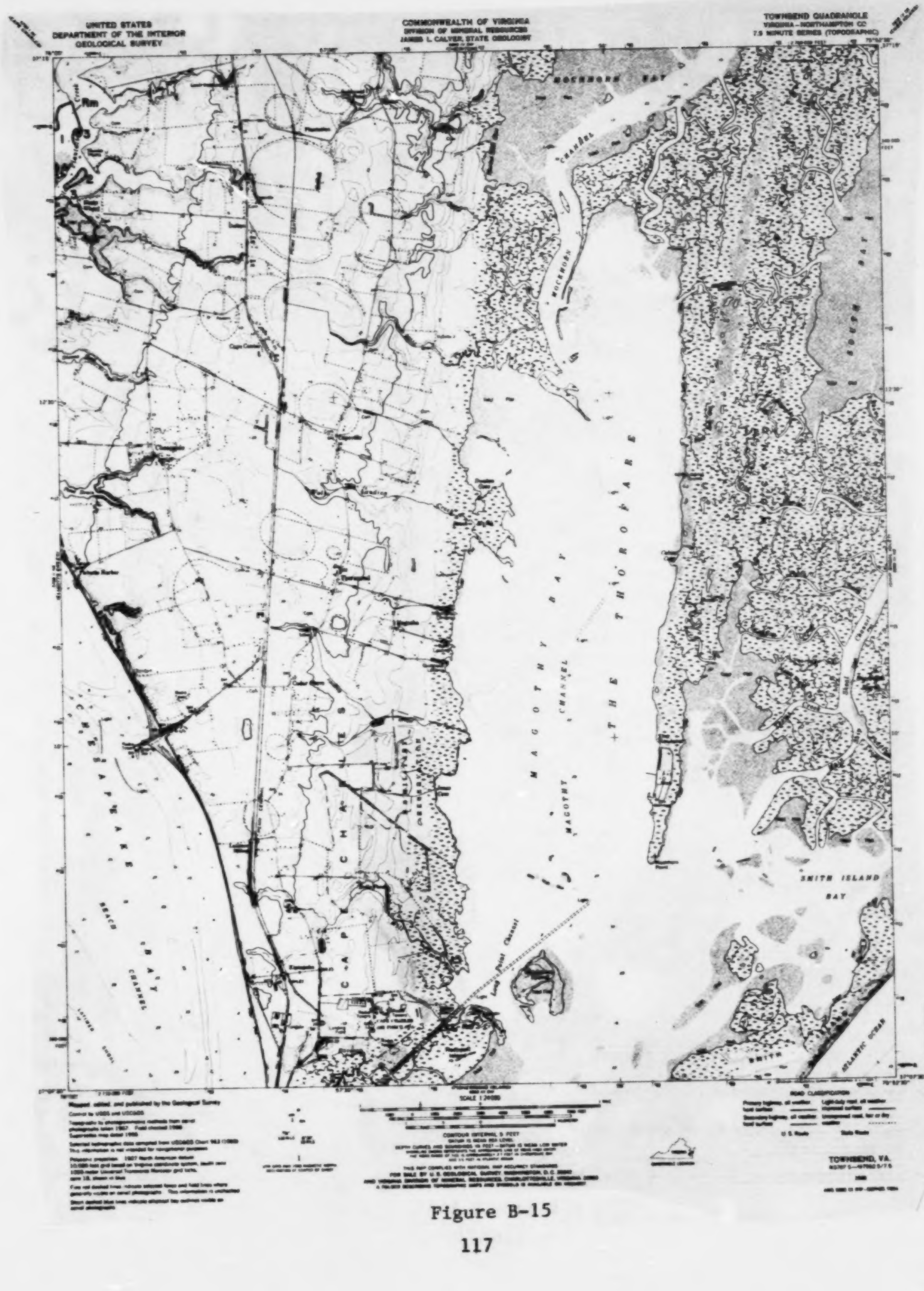
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
REEDVILLE QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
GREAT WICOMICO
RIVER
COCKRELL
Bridge Neck
HARVEYS NECK
INGRAM BAY
CHESAPEAKE BAY
CREEK
Zm, Rm
1
2
3
REEDVILLE, VA.

Figure B-14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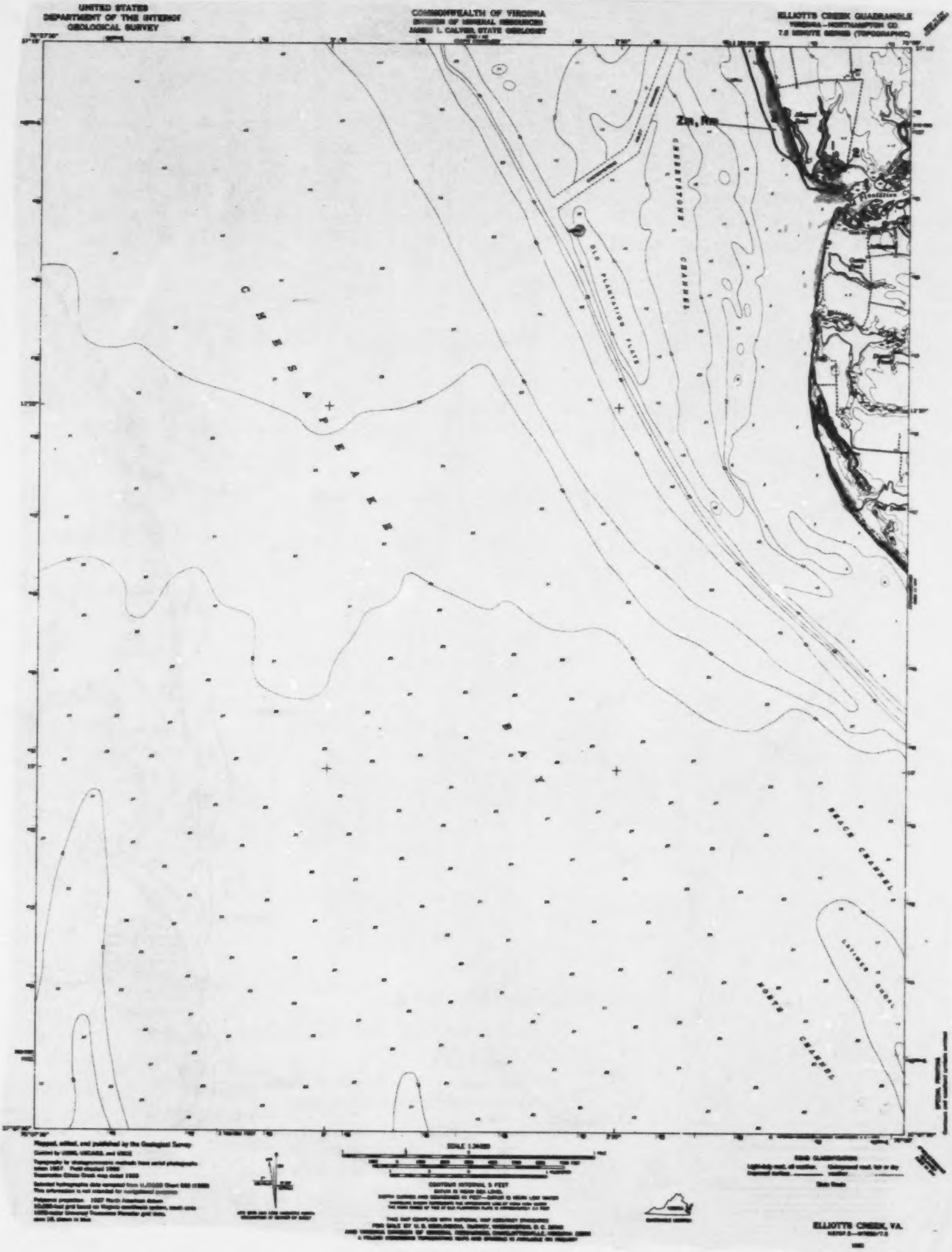
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
TOWNSEND QUADRANGLE
VIRGINIA–NORTHAMPTON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
MOCKHORN BAY
MOCKHORN CHANNEL
SOUTH BAY
MAGOTHY BAY
MAGOTHY CHANNEL
THE THOROFARE
SMITH ISLAND BAY
SMITH
ATLANTIC OCEAN
CHESAPEAKE BAY CHANNEL
CAPE CHARLES
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
TOWNSEND, VA.

Figure B-15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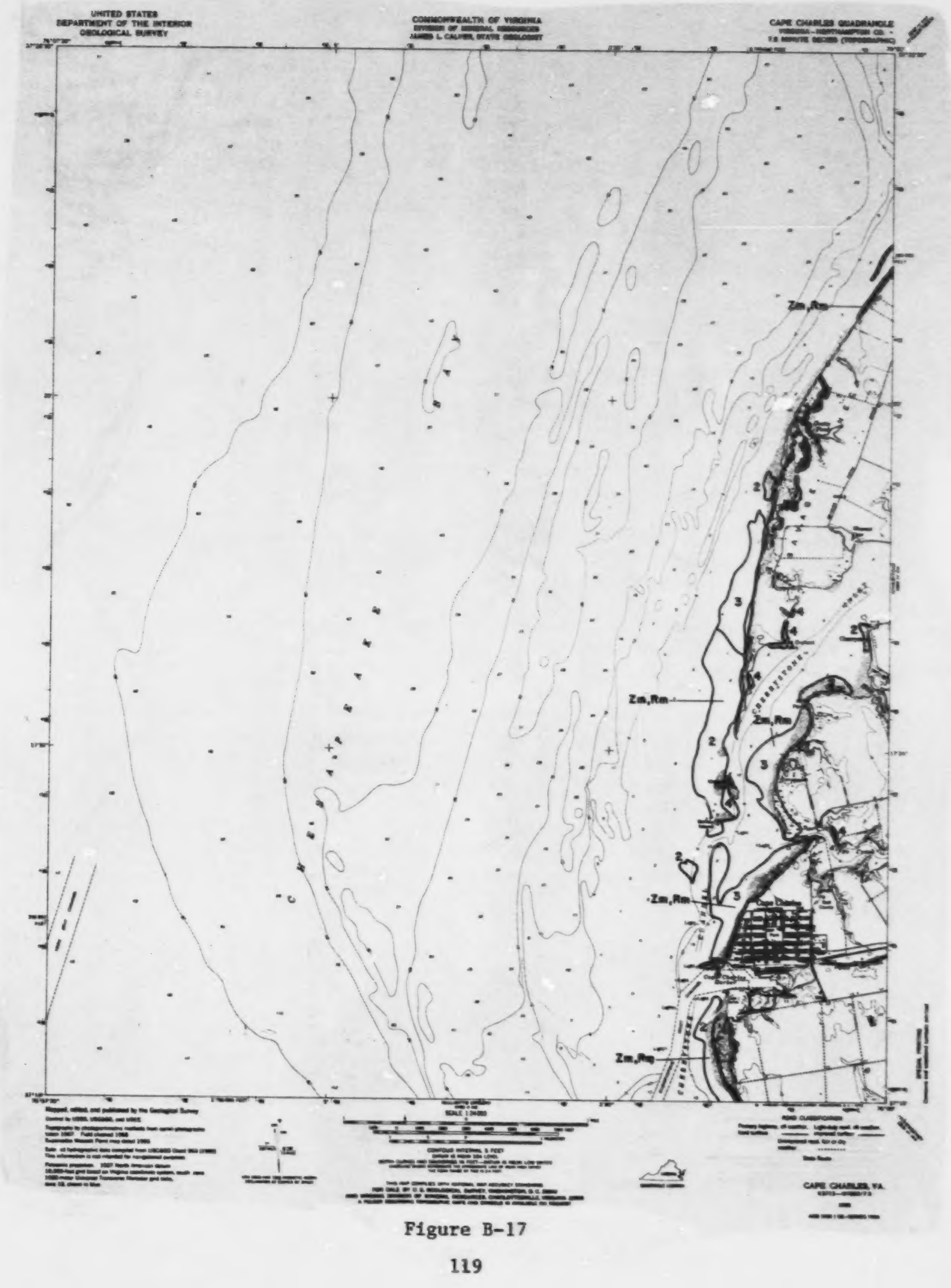
ELLIOTTS CREEK QUADRANGLE
VIRGINIA–NORTHAMPTON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
Zn, Rm
CHERRYSTONE CHANNEL
OLD PLANTATION FLATS
CHESAPEAKE
BAY
BEACH CHANNEL
NORTH CHANNEL
CONTOUR INTERVAL 5 FEET
ELLIOTTS CREEK, VA.

Figure B-16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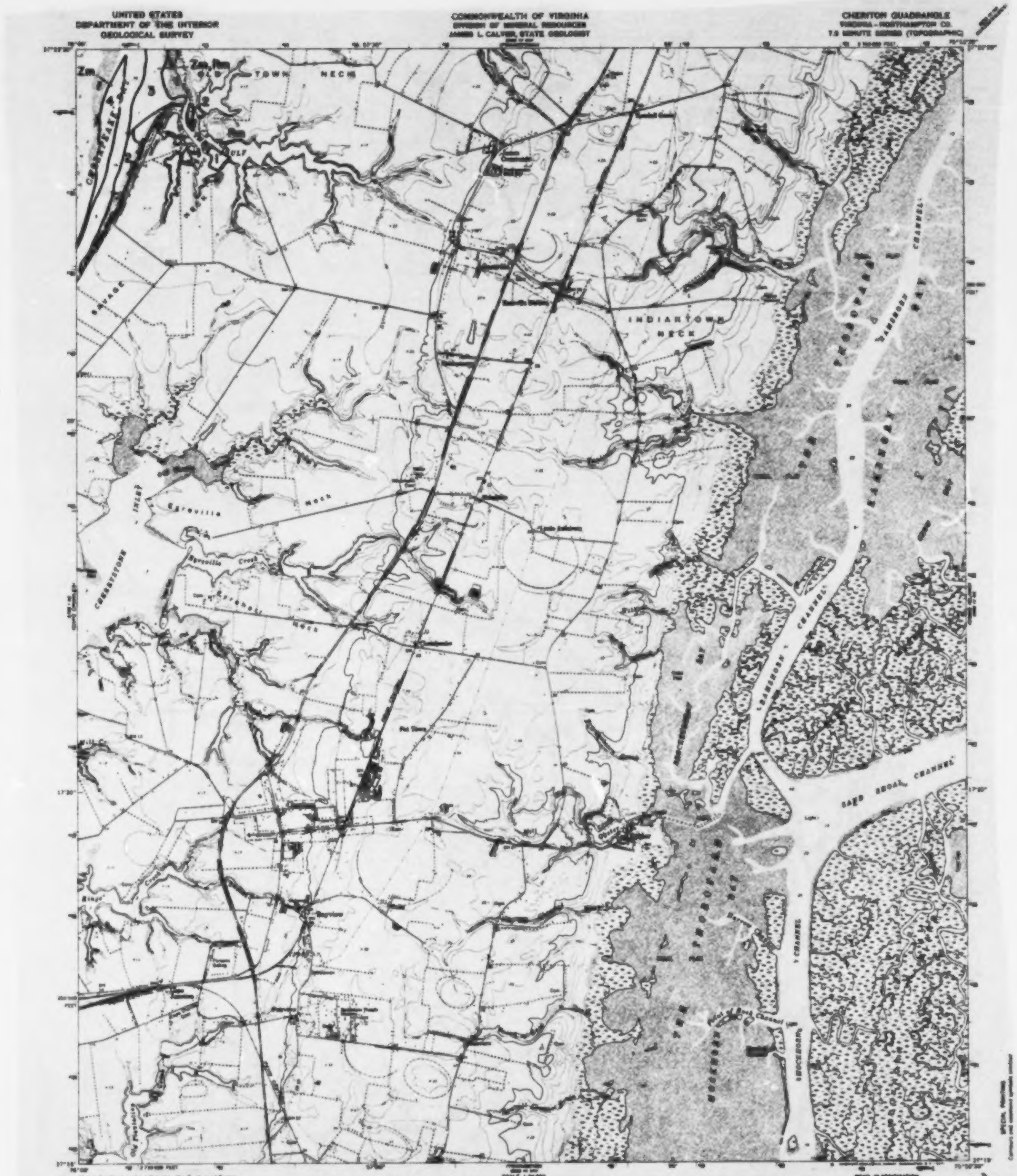
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
CAPE CHARLES QUADRANGLE
VIRGINIA—NORTHAMPTON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
Zm,Rm
2
3
4
Zm,Rm
Zm,Rm
2
3
2
Zm,Rm
3
Zm,Rm
2
CAPE CHARLES, VA.

Figure B-17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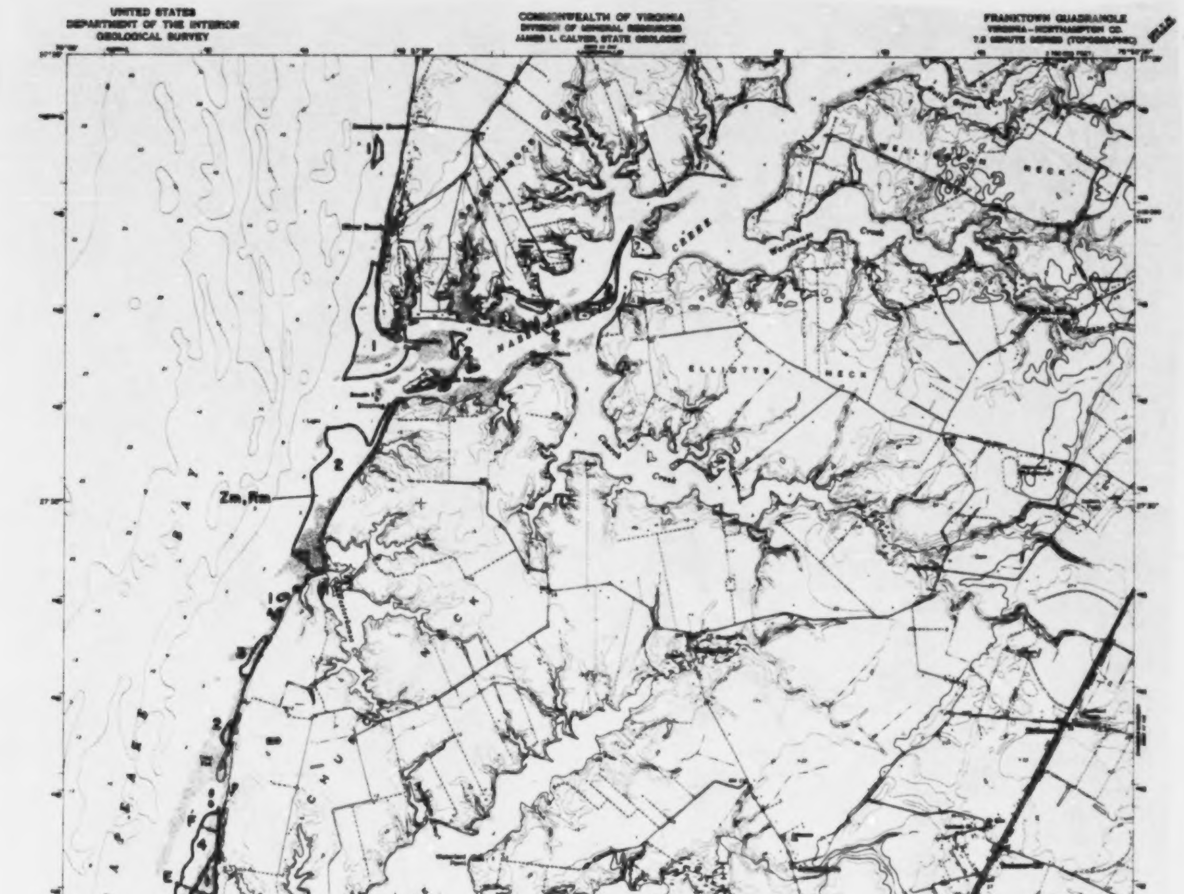
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
CHERITON QUADRANGLE
VIRGINIA–NORTHAMPTON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
Zm
Zm, Rm
OLD TOWN NECK
INDIANTOWN NECK
Eyreville Neck
Eyreville Creek
CHERRYSTONE INLET
SAND SHOAL CHANNEL
CHANNEL
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
Mapped, edited, and published by the Geological Survey
CHERITON, VA.

Figure B-18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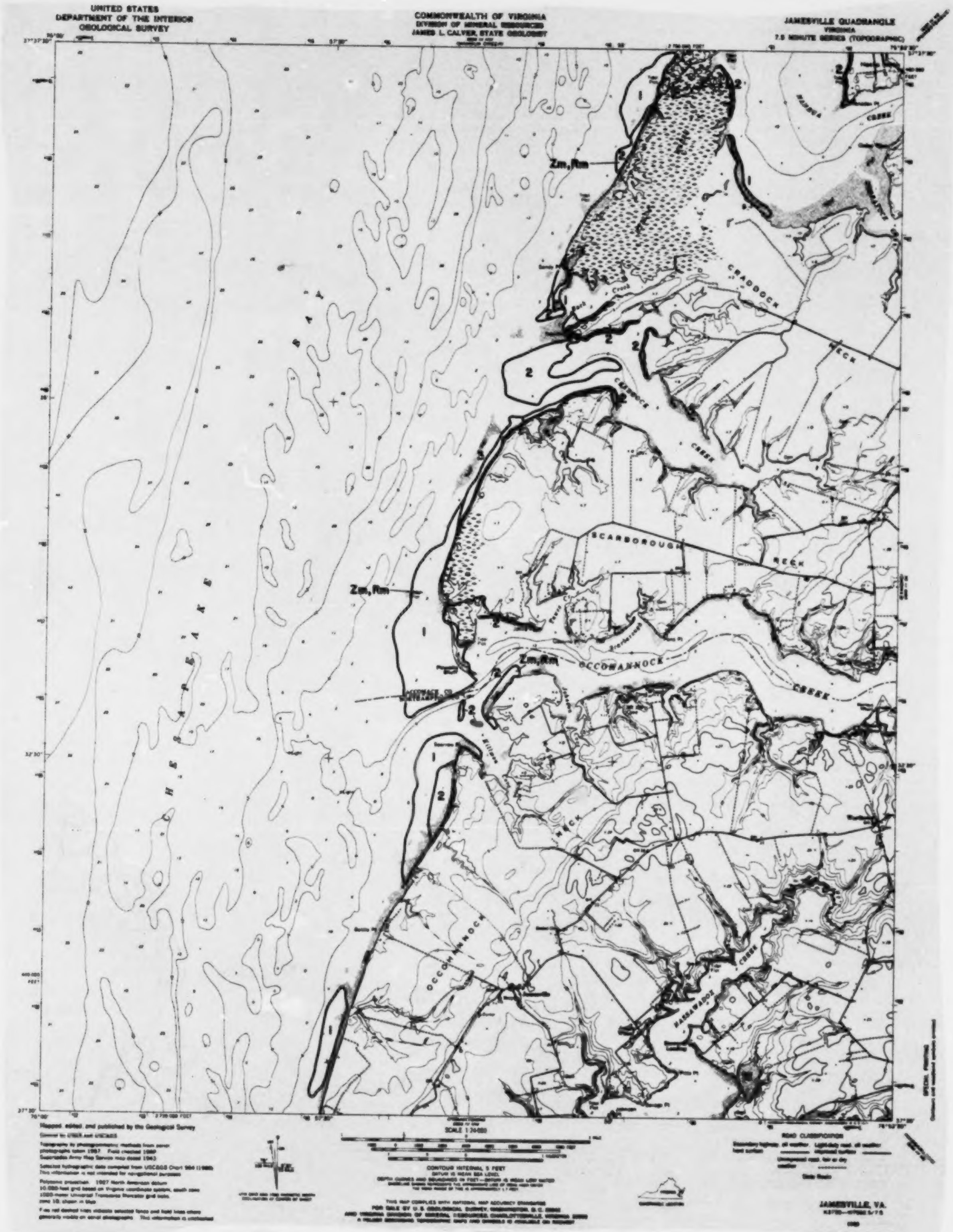
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
FRANKTOWN QUADRANGLE
VIRGINIA—NORTHAMPTON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
CHESAPEAKE BAY
ELLIOTTS NECK
WELLINGTON NECK
WARDTOWN NECK
OLDTOWN NECK
NASSAWADOX CREEK
HATTANGUN CREEK
Zm,Rm
1
2
3
4
A
B
C
D
E
F
CONTOUR INTERVAL 5 FEET
FRANKTOWN, VA.

Figure B-19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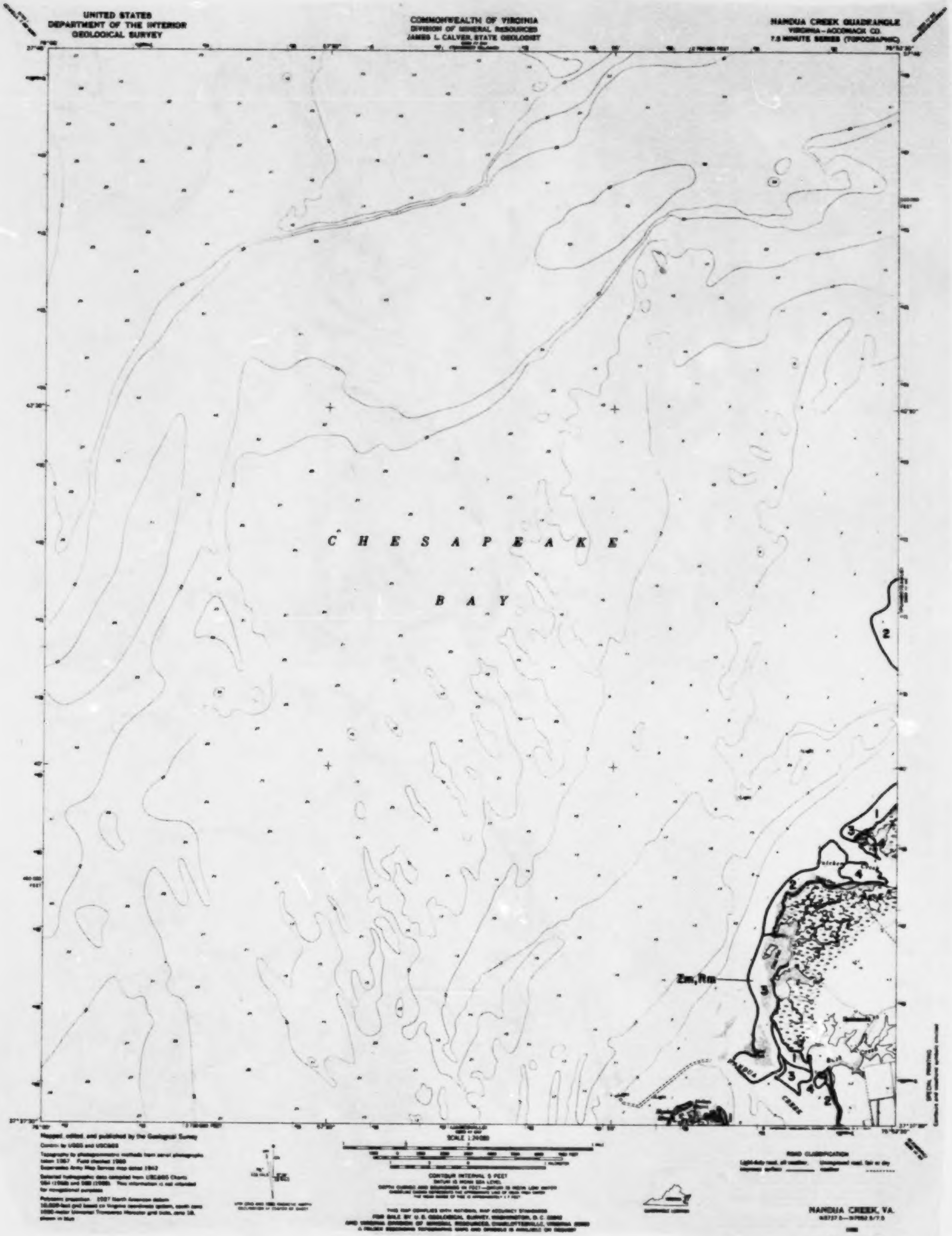
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
JAMESVILLE QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
Zm,Rm
CRADDOCK
NECK
CRADDOCK
CREEK
SCARBOROUGH
NECK
Zm,Rm
OCCOHANNOCK
CREEK
Zm,Rm
C H E S A P E A K E
B A Y
NECK
OCCOHANNOCK
NASSAWADOX
CREEK
1
2
CONTOUR INTERVAL 5 FEET
SCALE 1:24 000
JAMESVILLE, VA.

Figure B-20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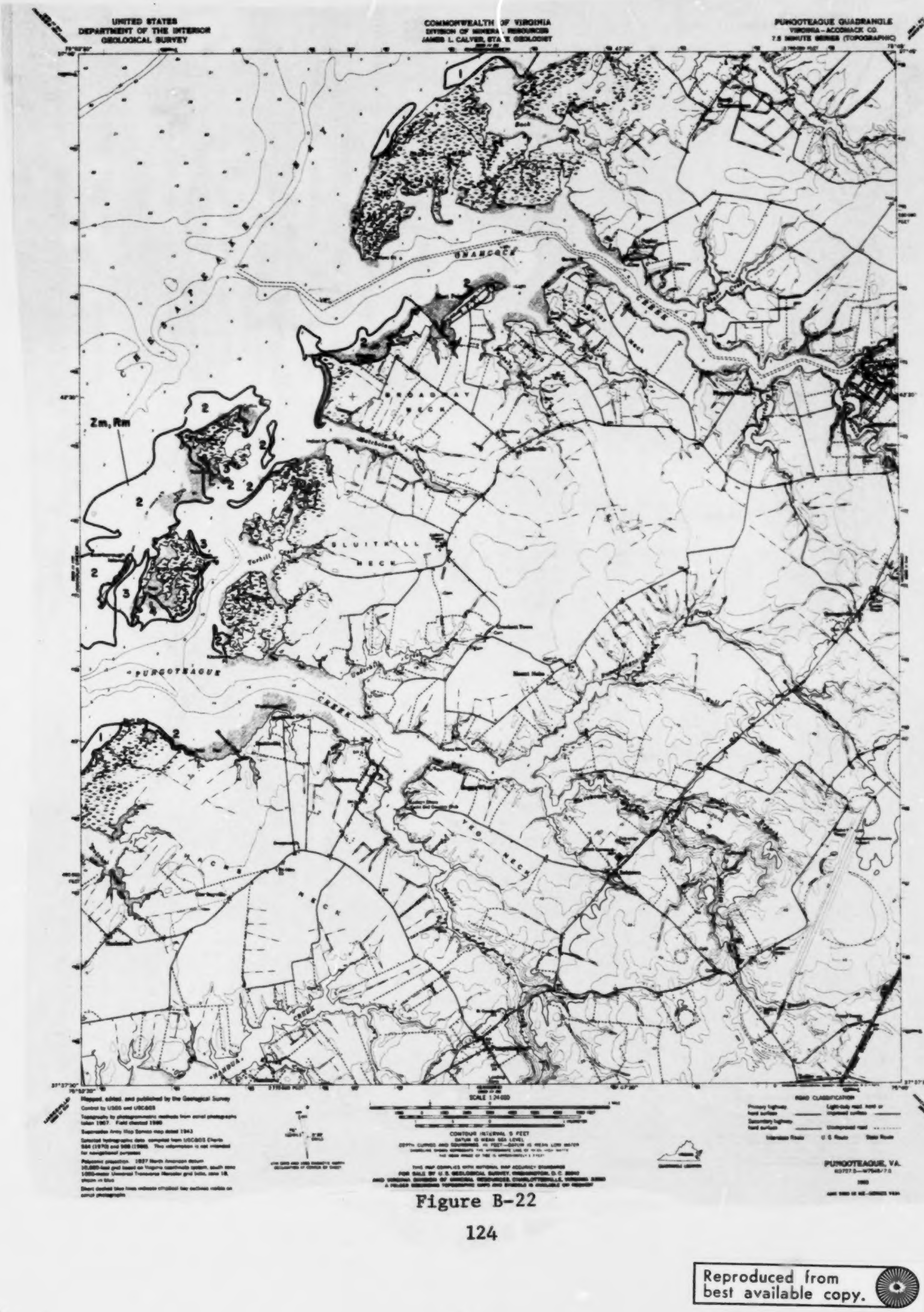
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
NANDUA CREEK QUADRANGLE
VIRGINIA-ACCOMACK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
CHESAPEAKE
BAY
2
1
3
4
2
Zm,Rm
3
3
4
2
CONTOUR INTERVAL 5 FEET
NANDUA CREEK, VA.

Figure B-21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COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
PUNGOTEAGUE QUADRANGLE
VIRGINIA–ACCOMACK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
ONANCOCK
CREEK
BROADWAY NECK
Zm, Rm
1
2
3
PUNGOTEAGUE
CREEK
NECK
Mapped, edited, and published by the Geological Survey
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
PUNGOTEAGUE, VA.

Figure B-22

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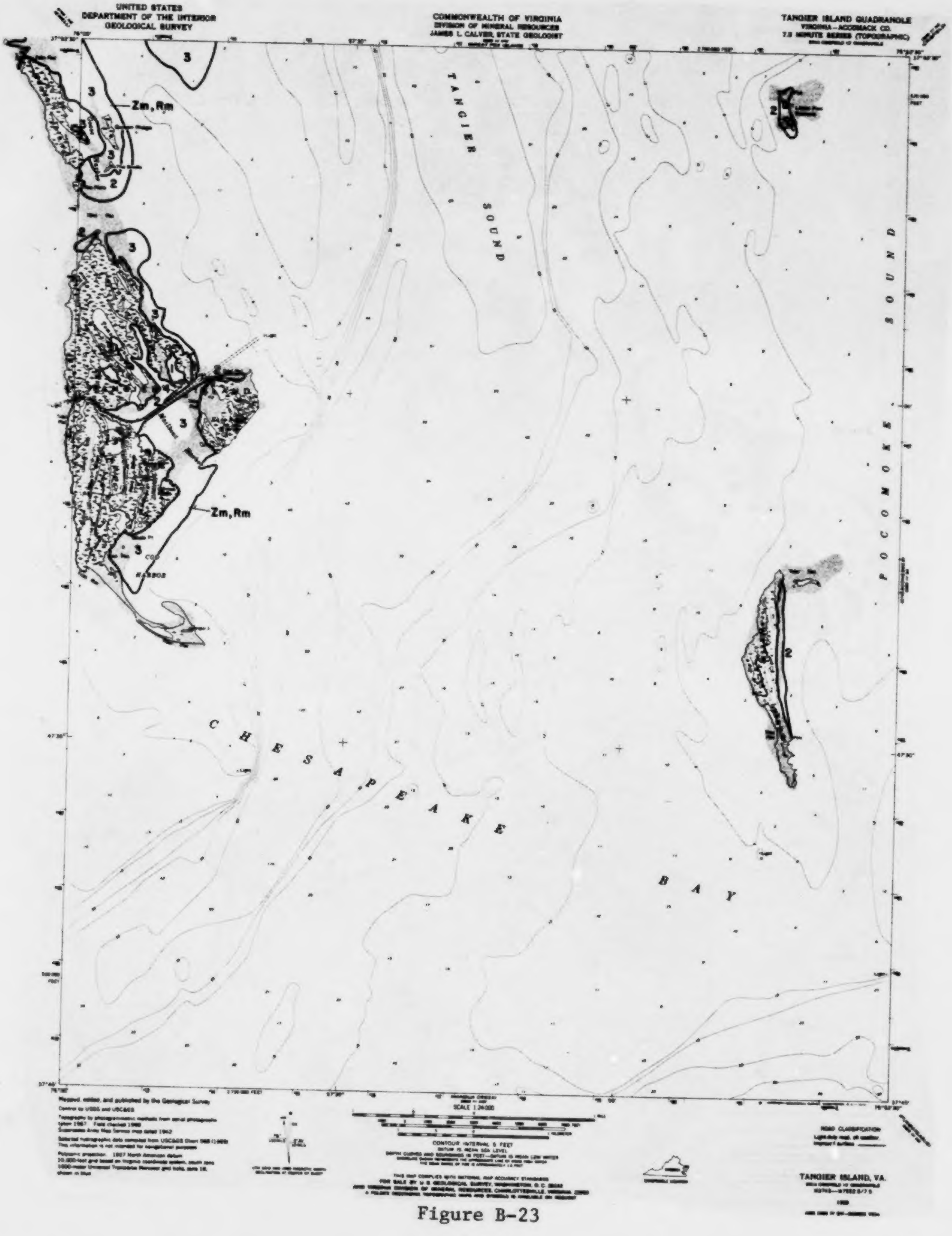
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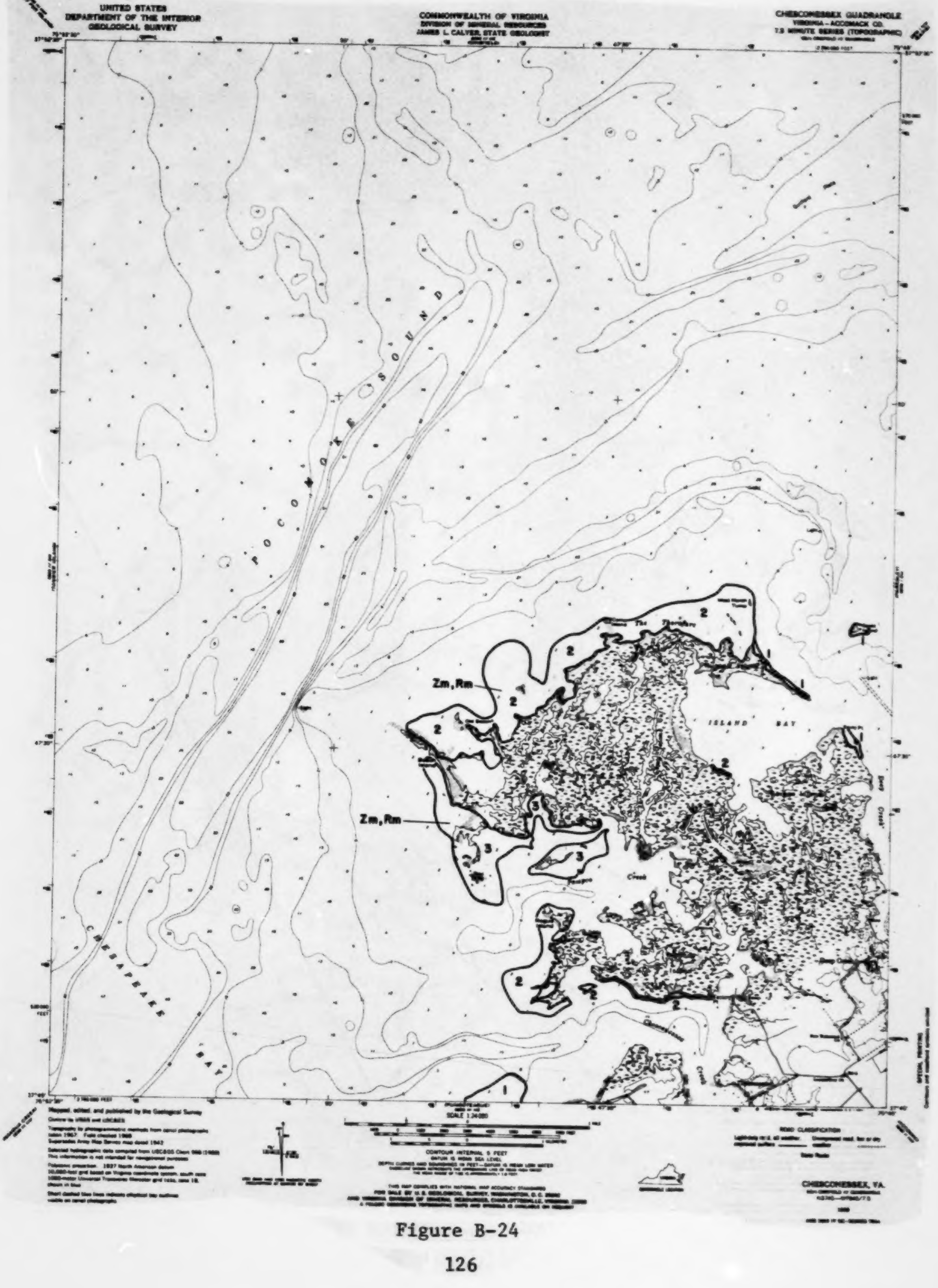
GEOLOGICAL SURVEY
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
TANGIER ISLAND QUADRANGLE
VIRGINIA—ACCOMACK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
TANGIER SOUND
POCOMOKE SOUND
CHESAPEAKE BAY
3
2
Zm, Rm
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
TANGIER ISLAND, VA.

Figure B-23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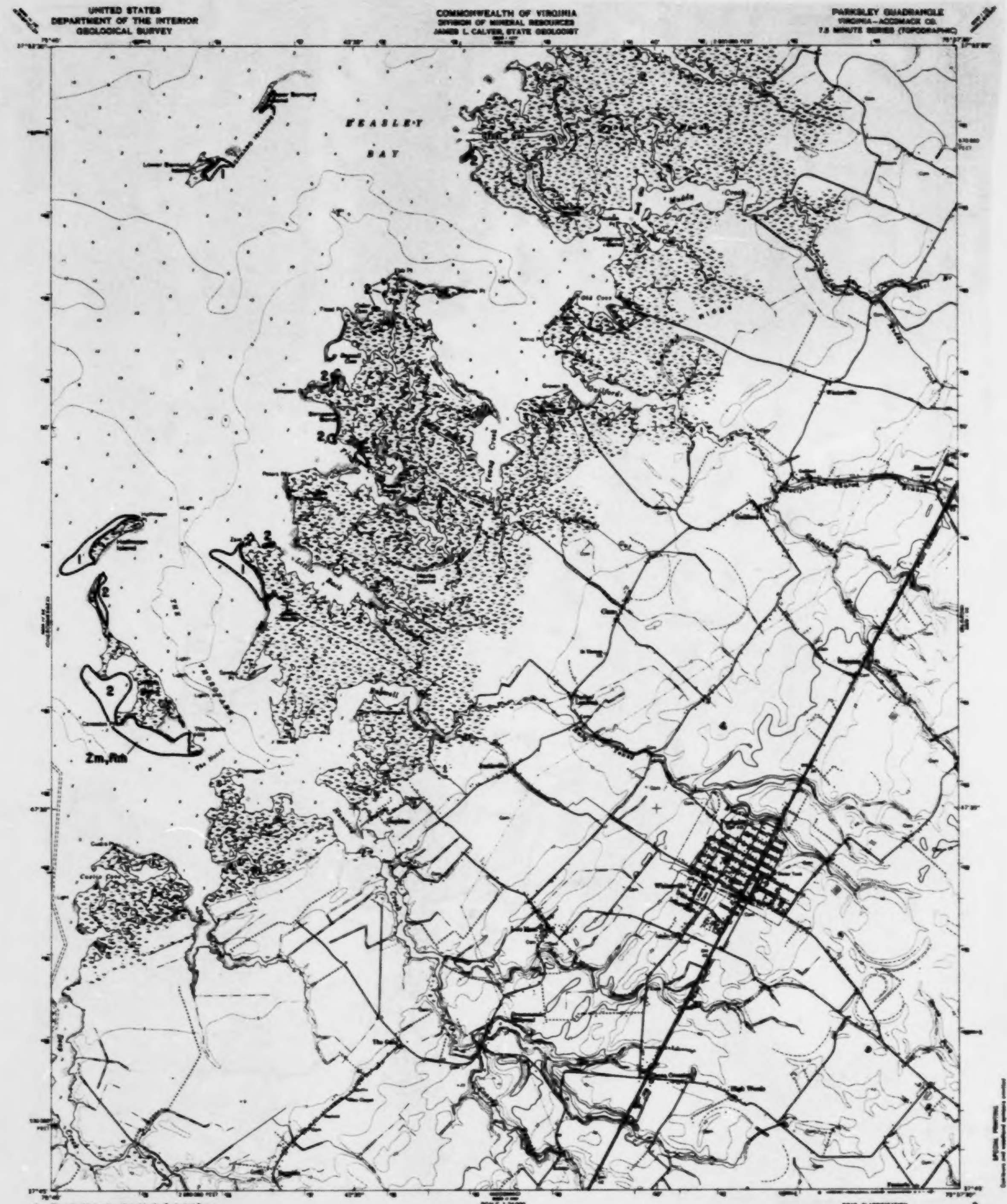
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
CHESCONESSEX QUADRANGLE
VIRGINIA – ACCOMACK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
POCOMOKE SOUND
CHESAPEAKE BAY
ISLAND BAY
Zm,Rm
Zm,Rm
1
1
2
2
2
2
2
2
2
3
3
3
3
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
CHESCONESSEX, VA.

Figure B-24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DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
PARKSLEY QUADRANGLE
VIRGINIA—ACCOMACK CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
PEASLEY
BAY
THE THOROFARE
1
2
Zm,Rm
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
PARKSLEY, VA.
Mapped, edited, and published by the Geological Survey

Figure B-25

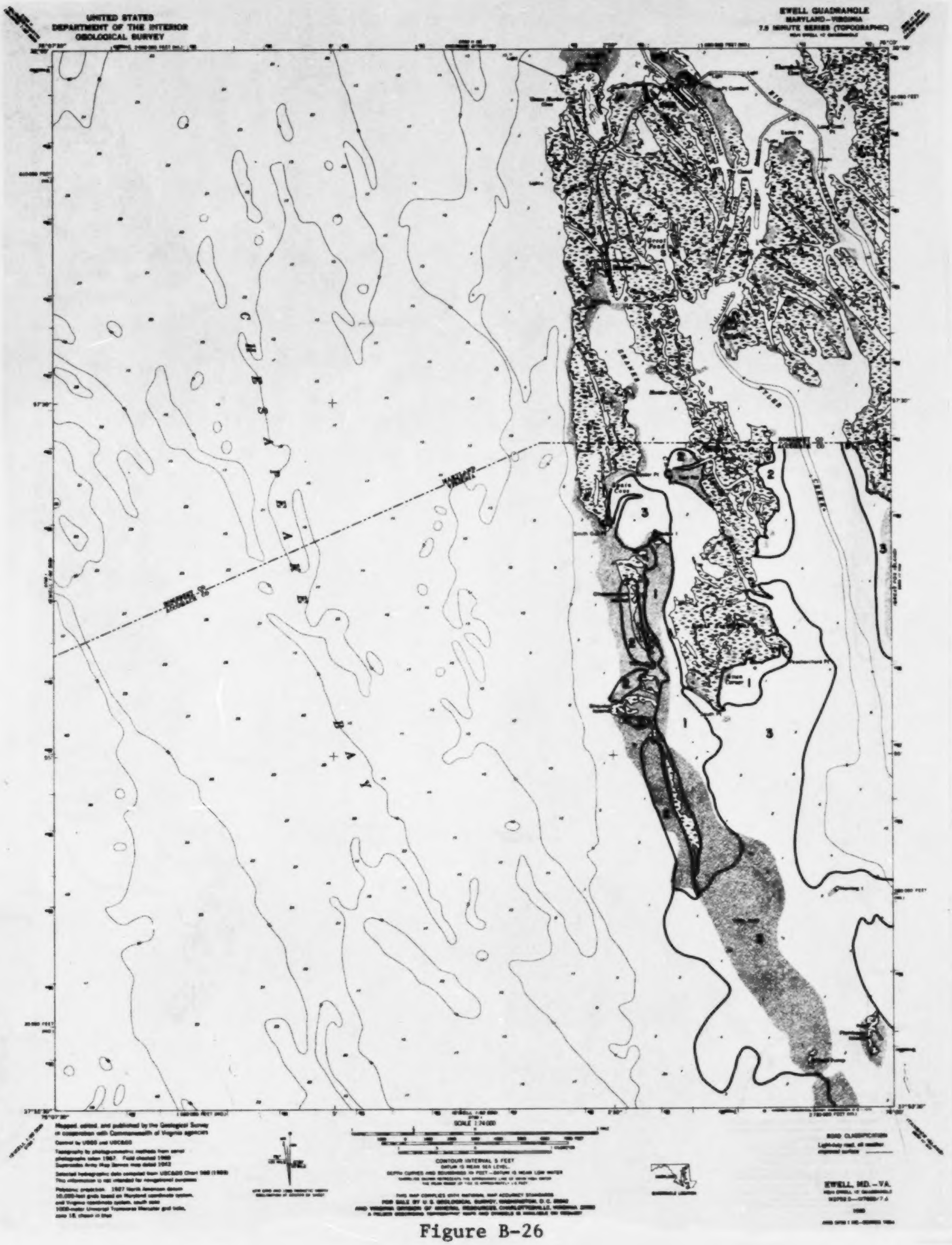
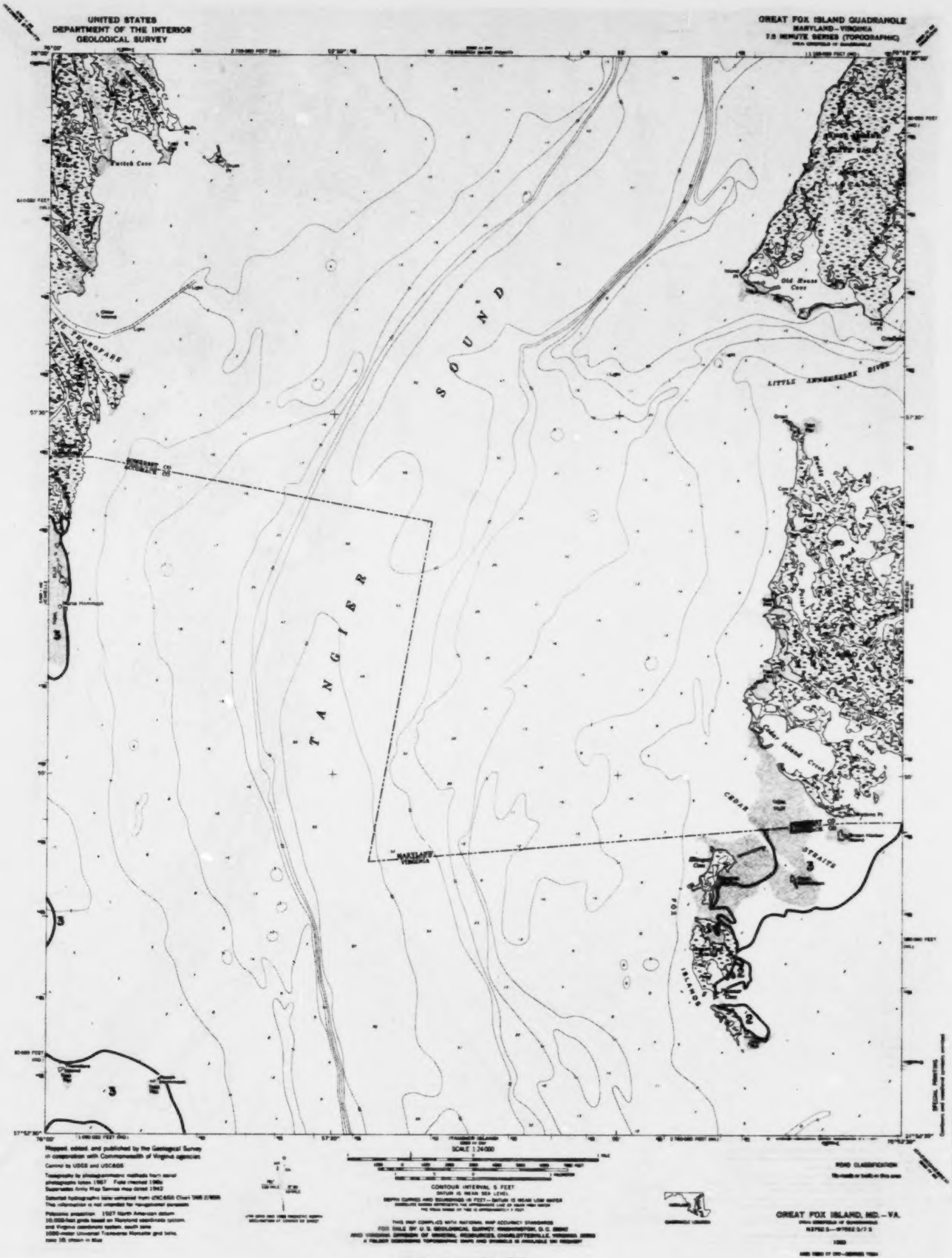

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
EWELL QUADRANGLE
MARYLAND—VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
CHESAPEAKE
BAY
MARYLAND
VIRGINIA
1
2
3
SCALE 1:24000
CONTOUR INTERVAL 5 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
EWELL, MD.–VA.

Figure B-26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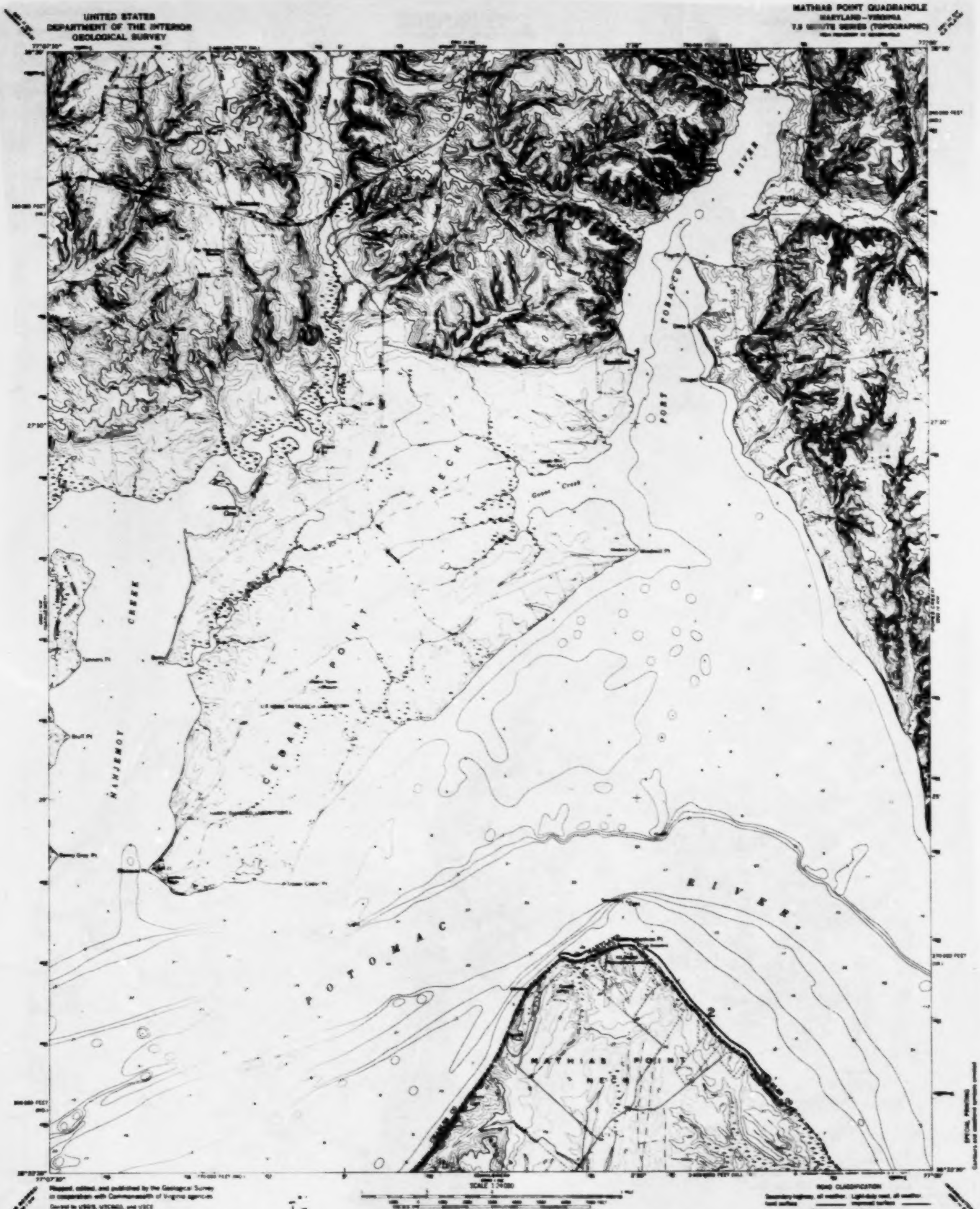
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
GREAT FOX ISLAND QUADRANGLE
MARYLAND–VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
TANGIER SOUND
LITTLE ANNEMESSEX RIVER
CEDAR STRAITS
FOX ISLANDS
Old House Cove
MARYLAND
VIRGINIA
3
2
SCALE 1:24 000
CONTOUR INTERVAL 5 FEET
GREAT FOX ISLAND, MD.–VA.

Figure B-27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GEOLOGICAL SURVEY
MATHIAS POINT QUADRANGLE
MARYLAND—VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
PORT TOBACCO RIVER
NECK
NANJEMOY CREEK
CEDAR POINT NECK
POTOMAC RIVER
MATHIAS POINT NECK
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
MATHIAS POINT, MD.—VA.

Figure B-28

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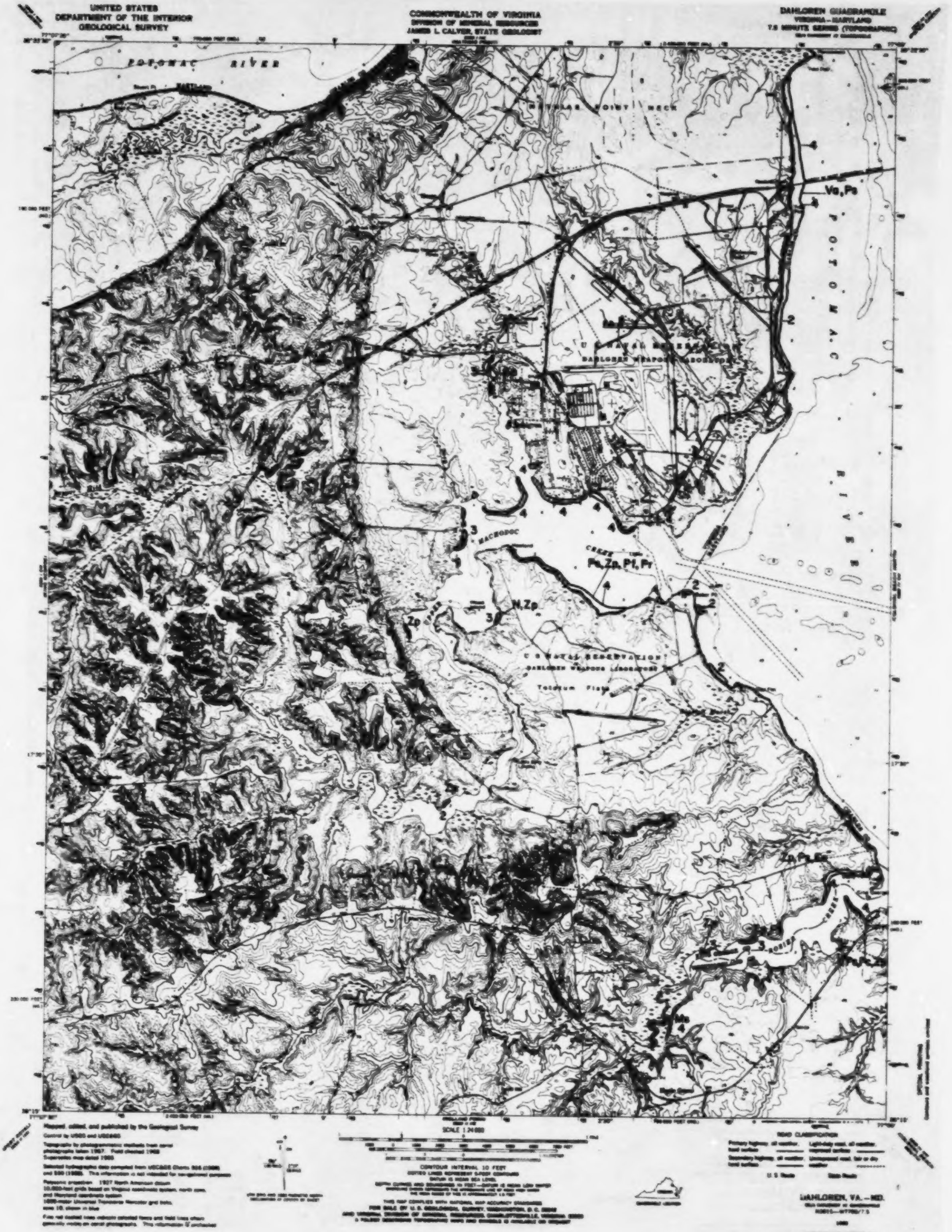
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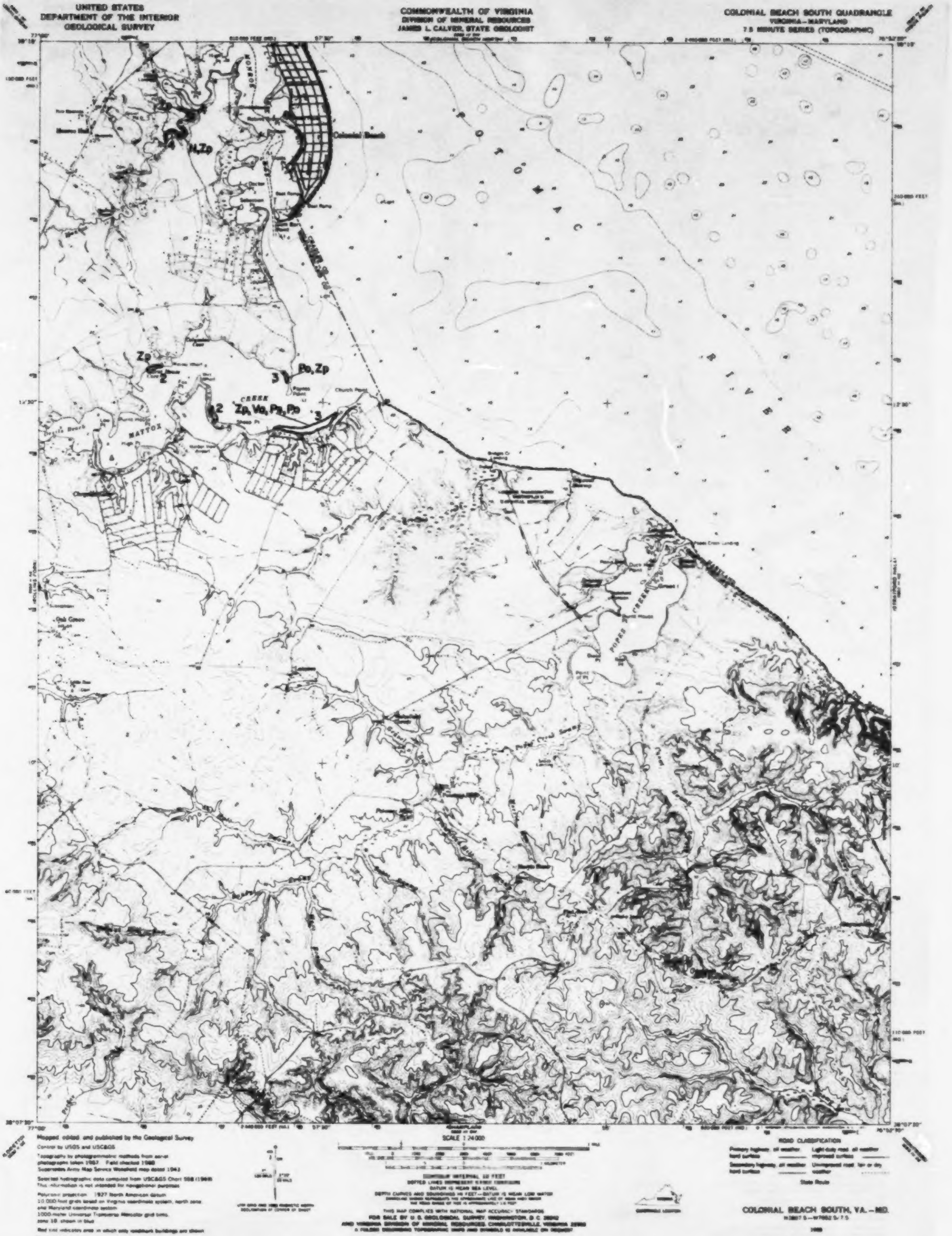
COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
DAHLGREN QUADRANGLE
VIRGINIA–MARYLAND
7.5 MINUTE SERIES (TOPOGRAPHIC)
POTOMAC RIVER
MARYLAND
POINT NECK
Va, Ps
POTOMAC RIVER
U S NAVAL RESERVATION
DAHLGREN WEAPONS LABORATORY
MACHODOC CREEK
Ps, Zp, Pl, Pr
N, Zp
Zp
Totuskey Flats
Zp, Ps, Ec
2
3
4
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
ROAD CLASSIFICATION
U S Route
State Route
DAHLGREN, VA.–MD.

Figure B-29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COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
COLONIAL BEACH SOUTH QUADRANGLE
VIRGINIA—MARYLAND
7.5 MINUTE SERIES (TOPOGRAPHIC)
MONROE
Colonial Beach
POTOMAC RIVER
N,Zp
Zp
2
3
Po,Zp
CREEK
2
Zp,Vo,Pe,Po
3
MATTOX
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
ROAD CLASSIFICATION
COLONIAL BEACH SOUTH, VA.—MD.

Figure B-30

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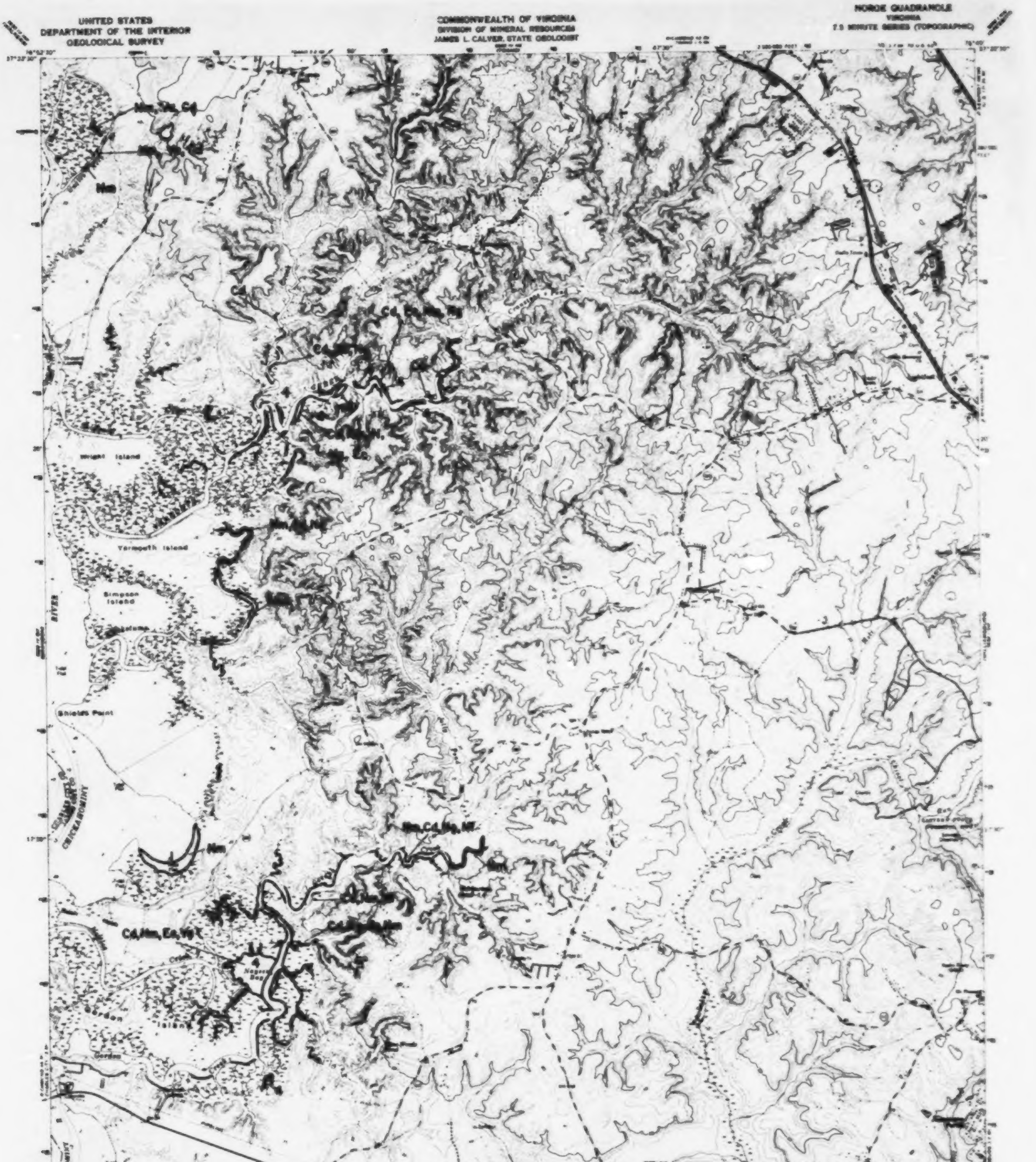
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COMMONWEALTH OF VIRGINIA
DIVISION OF MINERAL RESOURCES
JAMES L. CALVER, STATE GEOLOGIST
NORGE QUADRANGLE
VIRGINIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
Wright Island
Yarmouth Island
Simpson Island
Shields Point
Gordon Island
RIVER
CHICKAHOMINY
Cd,Mm,Eo,Yo,Y
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
NORGE, VA.

Figure B-31

APPENDIX C

DISTRIBUTION OF SAV PRESENTING STATION NUMBER, DATE OF SAMPLING, LOCATION OF STATION, SPECIES PRESENT AT THAT STATION AND THEIR RELATIVE ABUNDANCE AND GENERAL OBSERVATIONS AT THE STATION (SEE FIGURE 4 FOR STATION LOCATION)

Station	Date	Location	Species	Relative abundance	Observations
1	7-12-78	Salters Creek	none	-	No SAV observed in creek. *Sa* dominated marsh along shoreline.
2	7-12-78	Hampton River	none	-	No SAV observed from inside mouth to head of River. *Sa* marsh fringe.
3	9-14-78	Long Creek	none	-	No SAV observed from inside mouth to head of marsh channel. *Sp*, *Jr* marsh.
4	9-12-78	Plum Tree Island	*Zm*	*Zm* dominant	Transect site; sparse *Zm* along bottom which rapidly drops off in depth.
5	9-19-78	Plum Tree Island	*Rm*, *Zm*	*Rm* dominant *Zm* dominant	Transect site; broad SAV bed extending from *Sa* marsh shoreline.
6	9-15-78	James River-Warwick River	*Zp*	*Zp* occasional	Sparse *Zp* at head of river; no SAV observed in downstream areas.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative abundance	Observations
7	9-14-78	James River-Skiffes Creek	*Zp*	*Zp* occasional	Sparse *Zp* at head of creek; no SAV observed in downstream areas.
8	7-7-78	James River-College Creek	none	-	No SAV observed in creek system.
9	7-7-78	James River-Mill Creek	*Zp*	*Zp* dominant	*Zp* in shallow embayed area near mouth of creek, fringing along *Sc*, *Pv* marsh.
10	7-7-78	James River-Powhatan Creek	*Nm*	*Nm* dominant	Scattered along small marsh gut near head of creek; associated marsh vegetation *Pd*, *Pv*, *Sa*; only SAV area observed in creek system.
11	6-23-78	James River-Grays Creek	*Cd*	*Cd* occasional	No SAV found throughout most of creek. *Cd* observed floating near head of creek; associated marsh vegetation of *Pd*, *Ta*.
12	8-24-78	Chickahominy River-Nayses Bay	*Cd*, *Nm*, *Ec* *Va*	*Cd* dominant *Nm* dominant *Ec* frequent *Va* occasional	Large SAV bed approximately 300 m in width covering shallow bay; *Cd* and *Nm* dominant with other species observed occasionally throughout.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
13	8-24-78	Chickahominy River-Gordon Creek	*Cd*, *Ng*, *Ec*, *Nm*	*Cd* dominant *Ng* abundant *Ec* frequent *Nm* occasional	Small bed of SAV at head of freshwater marsh gut.
14	8-24-78	Chickahominy River-Gordon Creek	*Cd*, *Nm*, *Nf*	*Cd* dominant *Nm* abundant *Nf* abundant	Narrow (2m) SAV fringe along edge of *Pu*, *Za*
15	8-24-78	Chickahominy River-Gordon Creek	*Nm*, *Cd*, *Ng*, *Nf*	*Cd* abundant *Ng* frequent *Nf* occasional *Nm* dominant	Narrow fringe (2m) of SAV along freshwater marsh of *Pd*, *Ne*
16	8-24-78	Chickahominy River-Gordon Creek	*Nm*	*Nm* dominant	Narrow fringe (1m) of *Nm* along edge of mixed tidal swamp and marsh at head of creek channel.
17	8-24-78	Chickahominy River	*Nm*	*Nm* dominant	Scattered small patches (1m^2) of *Nm* along shoreline of large, shallow embayed area; depth <1m at low water.
18	8-24-78	Chickahominy River-Blackstump Creek	*Nm*	*Nm* dominant	Narrow fringe of *Nm* along creek channel bordering freshwater marsh.
19	8-24-78	Chickahominy River-Blackstump Creek	*Nm*, *Cd*, *Ng*	*Nm* dominant *Cd* frequent *Ng* occasional	Dense bed of SAV at head of creek channel; adjacent marsh of *Za*, *Pv*, *B*, *Ta*.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
20	6-23-78	Chickahominy River-Yarmouth Creek	*Nm*, *Cd*, *Ec*, *N*, *Ng*	*Nm* dominant *Cd* abundant *Ec* frequent *N* frequent *Ng* occasional	SAV bed fringing on band 1-2m wide along *Nl*, *Pd* marsh.
21	6-23-78	Chickahominy River-Yarmouth Creek	*Cd*, *Ec*, *Nm*, *Ng*	*Cd* dominant *Ec* dominant *Nm* abundant *Ng* occasional	SAV bed fringing in band 1-2 m wide along *Nl*, *Pd* marsh.
22	6-23-78	Chickahominy River-Yarmouth Creek	*Cd*	*Cd* dominant	*Cd* fringing in band 2m wide along *Nl* marsh; also growing between *Nl*.
23	6-23-78	Chickahominy River-Little Creek	*Cd*, *Ec*, *Ng*	*Cd* dominant *Ec* abundant *Ng* occasional	1-2 m wide bed along edge of channel fringing *Pd*, *Nl* marsh.
24	6-23-78	Chickahominy River-Little Creek	*Cd*	*Cd* dominant	1 m wide fringe along edge of *Pd*, *Nl* marsh.
25	7-11-78	Chickahominy River-Sunken Marsh	*Nm*, *N*	*Nm* dominant *N* occasional	*Pd* marsh channel with intermittent, narrow (1m) band of SAV along edge of marsh.
26	7-11-78	Chickahominy River-Old Neck	*Nm*, *N*, *Ng*,	*Nm* dominant *N* occasional *Ng* occasional	Freshwater marsh gut with narrow (1 m) band of SAV along channel edge.
27	7-11-78	Chickahominy River-Big Marsh Point	*Nm*, *N*	*Nm* dominant *N* occasional	Narrow (<1m) fringe of SAV along *Pc*, *Pv* marsh.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
28	7-11-78	Chickahominy River	*Nm*, *N*	*Nm* dominant *N* occasional	Scattered small patches of SAV along *Nl* marsh.
29	7-11-78	Chickahominy River-Uncles Neck Creek	*Nm*, *Cd*	*Nm* dominant *Cd* frequent	Narrow SAV fringe (1-2 m wide) along edge of *Pd*, *Za* marsh; silt bottom; deep channel with no vegetation present.
30	7-11-78	Chickahominy River-Uncles Neck Creek	*Va*, *Nm*, *Cd*	*Va* dominant *Cd* frequent *Nm* abundant	Small marsh gut with SAV covering bottom at head of channel; *Cd* and *Nm* along sides; *Va* in center; associated marsh vegetation *Pd*.
31	8-2-78	York River-Ware Creek	*Cd*, *N*, *Ng*, *Ec*, *Va*, *Po*	*Cd* abundant *N* frequent *Ng* frequent *Ec* occasional *Va* occasional *Po* occasional	SAV along channel bottom at head of creek; adjacent marsh of *Pd*, *Pv*, *Za*.
32	8-15-78	Pamunkey River-Cook Landing	*Cd*, *Nm*	*Cd* dominant *Nm* frequent	Small freshwater marsh gut with scattered SAV along channel edge.
33	8-16-78	Pamunkey River-Big Creek	*Cd*	*Cd* dominant	Narrow fringe of *Cd* along edge of *Pv* marsh.
34	9-5-78	Mattaponi River-Carbin Creek	*Cd*, *Pi*, *En*	*Cd* dominant *Pi* occasional *En* occasional	Sparse fringe of SAV along shoreline at head of creek.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
35	9-5-78	Mattaponi River-Burnt Mill Creek	*Cd*, *Zp*, *Ng*	*Cd* dominant *Zp* frequent *Ng* occasional	Fringe of SAV along edge of freshwater marsh.
36	7-5-78	Poropotank River-Guthrie Creek	*Zp*	*Zp* dominant	Shallow marsh gut at head of creek; *Zp* found scattered on channel bottom (<1m); associated marsh vegetation *Za*, *Sa*.
37	7-5-78	Poropotank River	*Pc*	*Pc* dominant	Main branch of river at head; dense stands of *Pc*, *Zm* wide along channel; associated vegetation is wooded swamp with abundant floating *L*.
38	7-5-78	Poropotank River	*Cd*, *Ec*, *Zp*	*Cd* abundant *Ec* abundant *Zp* occasional	Small freshwater marsh gut near head of river; narrow (.5m) SAV fringe along *Pd* marsh.
39	7-5-78	Poropotank River	*Cd*, *Zp*	*Cd* abundant *Zp* occasional	Scattered patches of SAV along edge of freshwater marsh in small gut; associated vegetation *Pd*, *Pv*, *Za*.
40	7-5-78	Poropotank River-Poplar Spring Branch	*Pc*, *Cd*, *Zp*	*Pc* dominant *Cd* frequent *Zp* occasional	Dense bed of *Pc* at head of creek branch covering channel bottom; associated marsh vegetation *Pd*, *Pv*, *Za*; *Cd* generally only along edge of marsh.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
41	7-14-78	York River- Aberdeen Creek	*Zp*	*Zp* abundant	Scattered *Zp* along *Sa* marsh shoreline at head of creek.
42	7-14-78	York River- Timberneck Creek	none	-	No SAV observed in creek system.
43	9-15-78	York River- Sarah Creek	none	-	No SAV observed in creek system.
44	8-15-78	Brown's Bay-A	*Zm*, *Rm*	*Zm* dominant *Rm* abundant	Transect site; broad SAV bed approximately 400 m wide of mixed *Zm* and *Rm*; adjacent marsh of *Sa*.
45	8-15-78	Brown's Bay-B	*Zm*, *Rm*	*Zm* dominant *Rm* dominant	Transect site; broad SAV bed approximately 400 m wide of mixed *Zm* and *Rm*; adjacent marsh of *Sa*.
46	8-16-78	Ware Neck-B	*Zm*, *Rm*	*Zm* dominant *Rm* dominant	Transect site; broad SAV bed approximately 400 m wide interspersed with submerged, parallel bars.
47	8-16-78	Ware Neck-A	*Zm*, *Rm*	*Zm* dominant *Rm* dominant	Transect site; broad SAV bed with inshore shallow zone of largely *Rm*; deeper offshore zone dominated by *Zm*.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
48	8-17-78	East River-B	*Zm*, *Rm*	*Zm* dominant *Rm* dominant	Transect site; broad SAV bed approximately 350m wide; shallow inshore zone of *Rm* grades to deeper offshore zone of *Zm*
49	8-17-78	East River-A	*Zm*, *Rm*	*Zm* dominant *Rm* dominant	Transect site; broad SAV bed approximately 300m wide; shallow inshore zone of *Rm* grades to deeper offshore zone of *Zm*.
50	9-7-78	Horn Harbor-B	*Zm*, *Rm*	*Zm* dominant *Rm* frequent	Transect site; broad SAV bed dominated by *Zm* extends approximately 300m offshore of sandbar; inshore of bar is area of silty bottom that is sparsely vegetated.
51	9-6-78	Horn Harbor-A	*Zm*, *Rm*	*Zm* dominant *Rm* occasional	Transect site; 300m wide SAV bed extending offshore from *Sa* marsh; zone of mixed *Zm* and *Rm* near shore grades to *Zm* only offshore.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
52	8-1-78	Vaucluse Shores	*Zm* , *Rm* , *Zp*	*Zm* dominant *Rm* dominant *Zp* rare	Transect site; extensive SAV bed inshore of large sandbar; width varies from 200m at north end to 700m at southern end; *Rm* dominates shallow areas with *Zm* dominating deeper zones; sparse *Zp* at north end.
53	6-21-78	Piankatank River-Carver's Creek	*Ec*, *Pc*, *Zp*, *Pc*, *Cd*	*Ec* abundant *Pc* abundant *Zp* abundant *Pc* frequent *Cd* occasional	Small freshwater marsh gut; SAV in dense bed covering bottom from inside mouth to head of creek.
54	6-21-78	Piankatank River	*N*	*N* dominant	Scattered patches *N* throughout shallow (<1m) embayed area; silty bottom.
55	6-21-78	Piankatank River	*Cv*	*Cv* dominant	Narrow bed 1-2m wide along edge of channel bordering mixed freshwater marsh/ wooded swamp community.
56	6-21-78	Piankatank River	*N*, *Cv*, *Nm*, *Ng*	*N* dominant *Cv* dominant *Nm* frequent *Ng* occasional	Bed 2m wide along edge of *Pd* marsh; average water depth 1m.
57	6-21-78	Piankatank River	*N*	*N* dominant	Scattered patches *N* along edge of freshwater marsh.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
58	6-7-78	Rappahannock River-Lancaster Creek	*Zp*	*Zp* dominant	Scattered *Zp* along shoreline; adjacent marsh of *Sa* and *Sc*.
59	6-9-78	Rappahannock River-Moratico Creek	*Zp*	*Zp* dominant	Scattered *Zp* along two small brackish marsh guts.
60	6-9-78	Rappahannock River-Moratico Creek	*Zp*	*Zp* dominant	*Zp* along marsh channel at head of creek; adjacent marsh of *Sa*, *Sc*, *Bh*.
61	6-15-78	Rappahannock River-Farnham Creek	*Zp*	*Zp* dominant	Sparse *Zp* fringe along edge of brackish marsh.
62	6-15-78	Rappahannock River-Farnham Creek	*Zp*	*Zp* dominant	Scattered *Zp* bordering brackish marsh.
63	6-20-78	Rappahannock River-Suggetts Point	*Pc*	*Pc* dominant	*Pc* in *Sp* marsh ditch that is slightly perched with restricted tidal flushing.
64	6-20-78	Rappahannock River-Neals Point	*C*, *Rm*	*C* frequent *Rm* frequent	Sparse coverage of SAV along small, marsh creek channel.
65	6-21-78	Rappahannock River-Richardson Creek	*Cv*, *Zp*	*Cv* abundant *Zp* frequent	Head of creek branch with fringe of SAV along edge of marsh; adjacent marsh of *Pv*, *Ta*.
66	7-18-78	Rappahannock River-Totuskey Creek	*Zp*	*Zp* dominant	Sparse *Zp* along two brackish marsh guts near mouth of creek.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
67	7-13-78	Rappahannock River-Totuskey Creek	*Cv*	*Cv* dominant	Intermittent fringe of *Cv* along edge of freshwater marsh and tidal swamp.
68	6-6-78	Rappahannock River-Belleview Creek	*Zp*	*Zp* dominant	Scattered *Zp* along *Sc* dominated marsh gut.
69	6-8-78	Rappahannock River-Piscataway Creek	*Cd*, *Cv*, *Va*	*Cd* abundant *Cv* frequent *Va* frequent	Fringe of SAV along edge of *Pv*, *Pd*, *Nl*, *Ta* marsh.
70	6-8-78	Rappahannock River-Piscataway Creek	*Va*, *Cd*, *Ec* *Pn*	*Va* dominant *Cd* abundant *Ec* frequent *Pn* frequent	Dense SAV stands across bottom of main channel at head of creek; adjacent marsh of freshwater species including *Pv*, *Pc*, *Nl*, *Za*.
71	7-19-78	Rappahannock River-Jugs Creek	*Ec*, *Zp*	*Ec* frequent *Zp* frequent	Scattered SAV along edge of channel at mouth of creek.
72	7-20-78	Rappahannock River-Little Carter Creek	*Zp*	*Zp* dominant	Scattered *Zp* along edge of brackish marsh.
73	7-20-78	Rappahannock River-Little Carter Creek	*Cd*, *Nm*, *Zp*	*Cd* abundant *Nm* abundant *Zp* frequent	SAV along edge of marsh at head of creek channel.
74	6-21-78	Rappahannock River-Hoskins Creek	*Va*, *Cd*	*Va* dominant *Cd* frequent	SAV of mostly *Va* along channel bottom at head of creek; adjacent marsh of *Pv*.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
75	6-22-78	Rappahannock River-Mount Landing Creek	*Va*, *Cd*	*Va* dominant *Cd* frequent	SAV along edge of *Pv*, *Ta*, *Nl* marsh at head of creek.
76	8-3-78	Rappahannock River-Cat Point Creek	*Cd*, *Nm*, *Ng*	*Cd* abundant *Nm* abundant *Ng* occasional	Fringe of SAV along small marsh gut; adjacent marsh of *Pv*, *Sc*.
77	8-3-78	Rappahannock River-Cat Point Creek	*Cd*, *Pi*	*Cd* dominant *Pi* occasional	SAV in dense stands across channel bottom at head of creek.
78	9-27-78	Rappahannock River-Quioccasin Creek	*Cd*	*Cd* dominant	Fringe of *Cd* along *Sc*, *Za* marsh shoreline at head of creek.
79	7-5-78	Rappahannock River-Farmers Hall Creek	*Cd*, *Va*	*Cd* abundant *Va* abundant	Pocket of SAV at head of creek branch; adjacent marsh *Pv*, *Pd*.
80	7-17-78	Rappahannock River-Hutchinson Swamp	*Cd*	*Cd* dominant	Scattered *Cd* at head of small creek; mixed fresh-water marsh species.
81	7-31-78	Rappahannock River-Elmwood Creek	*Cd*	*Cd* dominant	*Cd* at head of creek branch fringing along *Za*, *Pv* marsh.
82	7-19-78	Potomac River-Yeocomico River	none	-	No SAV observed from mouth to head of tidal river system.
83	7-19-78	Potomac River-Lower Machodoc Creek	*Zp*	*Zp* dominant	Sparse coverage of *Zp* along shoreline.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
84	7-19-78	Potomac River-Lower Machodoc Creek	*Zp*, *Ms*	*Zp* dominant *Ms* frequent	Narrow fringe of SAV along shoreline at head of creek.
85	7-19-78	Potomac River-Nomini Creek	*Zp*, *Cv*	*Zp* abundant *Cv* frequent	Scattered *Zp* along shoreline of head of creek; sparse *Cv* much of it floating; adjacent marsh of freshwater species; no SAV observed in downstream sections of creek.
86	7-18-78	Potomac River-Mattox Creek	*Pc*, *Va*, *Zp*, *Pr*	*Pc* dominant *Va* abundant *Zp* frequent *Pr* frequent	Broad (10m) SAV bed along sandy shoreline; depth approximately 1m.
87	7-18-78	Potomac River-Mattox Creek	*Zp*	*Zp* dominant	Small area of *Zp* scattered along shoreline; depth <1m.
88	7-18-78	Potomac River-Mattox Creek	*C*, *Zp*	*C* abundant *Zp* frequent	Scattered SAV along shoreline; associated marsh of *Sa*, *Sc*.
89	7-18-78	Potomac River-Mattox Creek	*Zp*, *Pr*, *Pc*	*Zp* abundant *Pr* abundant *Pc* frequent	SAV bed 5-10m wide along shoreline; located behind sand spit at mouth of creek.
90	7-18-78	Potomac River-Monroe Creek	*Zp*, *N*	*Zp* dominant *N* frequent	Head of creek; intermittent dense fringe of *Zp* along marsh; *N* locally abundant.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
91	7-18-78	Potomac River-Rosier Creek	*Pc*, *Ps*, *Ec*, *Zp*, *Va*, *Pr*	*Pc* dominant *Ps* abundant *Ec* occasional *Zp* occasional *Va* occasional *Pr* occasional	Broad SAV bed (10-20m wide) along shoreline of embayed area; water depth 0.5-2.0; *Ps* dominates in areas.
92	7-18-78	Potomac River-Rosier Creek	*Ms*, *Zp*	*Ms* dominant *Zp* frequent	Marsh channel at head of creek; dense stands of *Ms* across width of creek; adjacent marsh of *Za*, *Pd* *Ta*, *Sc*.
93	7-18-78	Potomac River-Rosier Creek	*Zp*, *Ms*	*Zp* abundant *Ms* frequent	Sparse occurrence of SAV along shoreline; *Zp* more abundant fringing along edge of *Sa* marsh.
94	7-18-78	Potomac River-Rosier Creek	*Ps*, *Zp*, *Pr*. *Ec*	*Ps* dominant *Zp* frequent *Pr* occasional *Ec* occasional	Intermittent SAV fringe along shoreline of creek; 0.5-2.0m water depth, *Zp* locally abundant.
95	7-18-78	Potomac River-Upper Machodoc Creek	*Pc*, *Zp*, *Va*, *Po*, *Pr*	*Pc* dominant *Zp* frequent *Va* frequent *Po* frequent *Pr* occasional	SAV bed 10-20m wide along shoreline near mouth of creek; sandy bottom with 1-2m depth.
96	7-18-78	Potomac River-Upper Machodoc Creek	*N*, *Zp*	*N* dominant *Zp* frequent	Small (<1m) patches of SAV fringing *Sa*, *Sc* marsh.

(continued)

APPENDIX C (continued)

Station	Date	Location	Species	Relative Abundance	Observations
97	7-18-78	Potomac River-Upper Machodoc Creek	*Zp*	*Zp* dominant	Scattered patches of *Zp* along edge of *Sa*, *Sc* marsh.
98	7-18-78	Potomac River-Upper Machodoc Creek	*Zp*	*Zp* dominant	Sparse coverage of *Zp* along sandy shoreline.
99	7-18-78	Potomac River-Upper Machodoc Creek	*Zp*	*Zp* dominant	Large areas of scattered *Zp* along shallow flats on both sides of channel near head of creek branch.
100	8-9-78	Potomac River-Rt. 301 Bridge	*Pr*, *Va*	*Pr* dominant *Va* abundant	Broad fringe of SAV along shoreline; grades from *Pr* near shore to *Va* in deeper areas offshore.

APPENDIX D

DATA DERIVED FROM TRANSECT ANALYSIS AT SEVENTEEN LOCATIONS PRESENTING DATE AND TIME OF TRANSECT SAMPLING, DISTANCE FROM SHORELINE (m), ELEVATION (dm), PERCENT COVER OF ZOSTERA AND RUPPIA ($0.1m^2$), BOTTOM TYPE AND GENERAL OBSERVATIONS

TABLE D1: PLUM TREE ISLAND–TRANSECT A[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-12-78	1045	0	+ .7	-	-	Peat	Eroded peat block from adjacent marsh.
"	1046	10	- 2.4	-	-	Fine Sand	Bare sand, no vegetation.
"	1048	20	- 2.6	-	-	"	
"	1050	30	- 3.5	20	-	"	Zm appears at 26m.
"	1052	40	- 3.7	30	-	"	Zm scattered.
"	1053	50	- 4.8	60	-	"	Zm common last 10m.
"	1054	60	- 6.1	-	-	"	Bare sand sparse Zm in vicinity.
"	1055	70	- 6.6	-	-	"	Sparse Zm.
"	1056	80	- 7.9	-	-	"	Patches of Zm nearby.
"	1057	90	- 9.2	-	-	"	Scattered Zm.
"	1100	100	- 9.6	10	-	"	Small patch Zm.
"	1101	110	-11.0	0	-	"	No Zm observed in vicinity.
"	1103	120	-11.1	trace	-	"	A few sprigs Zm only.

(continued)

APPENDIX D (continued)

TABLE D1 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm $(0.1m^2)$	% Rm $(0.1m^2)$	Bottom Type	Observations[5]
9-12-78	1105	130	-11.1	0	-	Fine Sand	Bare sand, no vegetation in vicinity.

[1] @ 1030 hrs. salinity = 20.3 ppt
surface water temperature = 24°C

[2] EDST

[3] Bearing of 60°mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[5] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D2: PLUM TREE ISLAND-TRANSECT B^{1}

Date	Time^{2}	Distance^{3} from shore-line (m)	Elevation^{4} (dm)	% Zm (0.1m^{2})	% Rm (0.1m^{2})	Bottom Type	Observations^{5}
9-12-78	1230	0	+2.3	-	-	Peat	Eroded blocks of marsh peat.
"	1231	10	- .6	-	-	Fine Sand	Uprooted Rm along bottom.
"	1232	20	-2.0	-	20	"	
"	1233	30	-3.4	-	30	"	Rm in small patches 1-3m diameter.
"	1233	40	-3.9	-	30	"	
"	1234	50	-4.3	-	10	"	Patchy Rm.
"	1236	60	-4.6	-	10	Silty Sand	
"	1235	70	-4.7	-	-	"	Bare area in between patches Rm.
"	1236	80	-4.2	-	-	"	
"	1237	90	-3.3	-	5	"	Sparse Rm.
"	1238	100	-3.8	-	5	Fine Sand	
"	1246	110	-4.8	-	10	Silty Sand	Patchy Rm.
"	1248	120	-5.3	-	20	"	
"	1250	130	-5.5	-	-	"	
"	1251	140	-5.6	-	5	"	Rm sparse coverage within large patch.
"	1252	150	-6.0	-	-	"	
"	1253	160	-6.1	-	-	"	Rm present in vicinity but sparse.
"	1254	170	-5.9	-	5	Silt	
"	1255	180	-5.9	-	5	Silty Sand	
"	1256	190	-6.0	-	-	"	
"	1257	200	-5.9	-	10	"	Silty bottom with sparse Rm last 100mn.

(continued)

APPENDIX D (continued)

TABLE D2 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
9-12-78	1305	210	-5.9	-	10	Silty Sand	
"	1307	220	-5.9	-	5	"	
"	1308	230	-5.8	-	-	"	Bare area between small patches Rm.
"	1309	240	-5.8	-	5	"	
"	1310	250	-5.7	-	15	"	Oysters scattered along bottom last 100m.
"	1311	260	-5.7	-	trace	"	
"	1313	270	-5.8	-	-	"	
"	1314	280	-5.8	-	5	"	
"	1315	290	-5.7	-	10	"	
"	1317	300	-6.1	-	-	"	
"	1325	310	-5.3	-	15	"	Rm sparse coverage within large patches.
"	1326	320	-5.3	-	5	"	
"	1327	330	-5.2	-	5	"	Wide, silty area with patchy Rm last 200m.
"	1328	340	-5.1	trace	50	"	First Zm observed mixed with Rm.
"	1329	350	-5.0	-	5	"	
"	1330	360	-4.9	trace	10	"	
"	1332	370	-4.3	10	10	"	370-380 Zm abundant.
"	1333	380	-4.3	15	5	"	
"	1334	390	-3.9	15	5	"	
"	1335	400	-3.6	20	-	"	
"	1345	410	-3.4	20	5	"	
"	1346	420	-2.8	20	10	"	

(continued)

APPENDIX D (continued)

TABLE D2 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-12-78	1347	430	-2.6	15	10	Silty Sand	
"	1349	440	-3.3	5	40	"	Zm mixed with abundant Rm.
"	1350	450	-3.4	-	5	"	
"	1351	460	-1.7	-	40	"	
"	1352	470	-1.3	-	5	Fine Sand	
"	1353	480	- .7	-	-	"	Bare area 480-490m scattered.
"	1354	490	- .8	-	-	"	Rm and Zm in vicinity.
"	1355	500	- .7	-	-	"	
"	1405	510	- .3	-	-	"	Bottom rises to wide, sandy bar.
"	1406	520	- .4	-	80	"	
"	1407	530	- .3	-	90	"	Large patches Rm with sparse Zm.
"	1408	540	- .1	-	70	Fine Sand	
"	1409	550	- .3	-	90	"	Continued large patches Rm with some open areas in between.
"	1410	560	- .3	-	50	"	
"	1411	570	- .6	-	30	"	Detrital Zm and Rm on bottom.
"	1412	580	- .4	trace	50	"	
"	1413	590	- .6	-	20	"	
"	1414	600	- .5	-	40	"	
"	1423	610	- .6	-	60	"	
"	1424	620	- .7	-	-	"	Bare sand, no vegetation in vicinity.
"	1425	630	- .6	-	-	"	Bare sand.

(continued)

APPENDIX D (continued)

TABLE D2 (continued)

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-12-78	1426	640	- .7	-	-	Fine Sand	
"	1427	650	- .9	-	-	"	No vegetation last 30m.
"	1428	660	-1.3	-	5	"	Dead Zm & Rm, sparse Zm.
"	1429	670	- .8	trace	-	"	Sparse Zm last 10m.
"	1430	680	-1.0	-	30	"	
"	1431	690	-1.3	trace	50	"	
"	1432	700	-1.3	-	70	"	
"	1442	710	-1.3	20	5	"	
"	1443	720	-1.6	30	5	"	
"	1445	730	-1.5	30	trace	"	Zm abundant last 30m.
"	1447	740	-1.8	25	-	"	Rm sparse, Zm abundant in vicinity.
"	1448	750	-1.9	30	-	"	
"	1449	760	-1.7	25	-	"	
"	1450	770	-1.8	-	80	"	Large patch Rm.
"	1451	780	-2.1	70	5	"	
"	1453	790	-2.3	40	5	"	
"	1454	800	-2.2	40	5	"	
9-19-78	1100	800	-2.2	40	5	"	
	1105	810	-2.2	5	40	"	
"	1100	820	-2.0	5	30	"	
"	1109	830	-2.3	20	60	"	Mounds of Zm and Rm with bare areas between.
"	1111	840	-2.5	40	5	"	Scattered clumps Zm and Rm.
"	1113	850	-2.6	20	20	"	
"	1115	860	-2.7	80	-	"	Large patch Zm, no Rm evident.
"	1116	870	-3.0	60	-	"	Rm present but very sparse.

(continued)

APPENDIX D (continued)

TABLE D2 (continued)

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-19-78	1118	880	-2.7	50	5	Fine Sand	
"	1120	890	-3.0	20	15	"	
"	1122	900	-3.0	10	trace	"	
"	1134	910	-3.1	40	-	"	Large patches Zm with traces of Rm.
"	1135	920	-3.7	30	trace	"	
"	1137	930	-3.3	70	-	"	Exposed patches of Zm rhizomes with healthy turions.
"	1138	940	-4.1	-	-	"	Bare area between large patches Zm and Rm.
"	1139	950	-4.2	20	40	"	
"	1140	960	-4.9	-	-	"	Large bare area.
"	1142	970	-4.6	60	-	"	
"	1143	980	-4.7	50	-	"	
"	1144	990	-4.7	70	-	"	Zm abundant throughout area.
"	1146	1000	-5.2	60	-	"	Rm in vicinity but sparse.
"	1158	1010	-5.7	80	-	"	
"	1200	1020	-6.1	50	5	"	
"	1202	1030	-6.1	70	-	"	Bottom sloping to deeper water, Zm abundant.
"	1204	1040	-6.3	50	-	"	
"	1205	1050	-6.8	40	-	"	No Rm last 30 m.
"	1206	1060	-6.8	70	-	"	Zm continues abundant throughout area.
"	1207	1070	-7.1	60	-	"	
"	1209	1080	-7.4	5	-	"	Zm very sparse last 10m.
"	1210	1090	-7.8	5	-	"	Small patch Zm.

(continued)

APPENDIX D (continued)

TABLE D2 (continued)

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
9-19-78	1212	1100	-8.0	-	-	Fine Sand	Bare sand, no vegetation evident in vicinity.

[1] @ 1030 hrs. 9-19-78 salinity = 20.7
surface water temperature = 24°C

[2] EDST

[3] Bearing of 70°mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[5] Zm = *Zostera marina*
Rm = *Ruppia maritima*

TABLE D3: BROWN'S BAY-TRANSECT A[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
8-15-78	1030	0	- .1	-	-	Peat	Eroded marsh peat on bottom.
"	1033	10	-2.1	-	20	Fine Sand	Vegetation begins at 6 m.
"	1036	20	-2.1	-	-	"	At 24 m Zm present.
"	1040	30	-2.7	5	30	"	10-30 m dead Zm & Rm lying on bottom.
"	1042	40	-2.8	-	-	"	30-40 m patches Zm and Rm.
"	1044	50	-3.0	30	50	"	
"	1046	60	-4.8	60	10	"	
"	1048	70	-5.4	80	5	"	Sponge prevalent on Zm.
"	1050	80	-5.2	90	5	"	
"	1052	90	-4.6	90	trace	"	
"	1055	100	-4.7	85	15	"	Mixed stands Zm & Rm.
"	1104	110	-5.4	50	trace	"	
"	1106	120	-5.9	70	"	"	Dead Zm & Rm on bottom.
"	1108	130	-6.1	60	5	"	
"	1110	140	-6.0	80	trace	"	
"	1112	150	-6.2	80	-	"	
"	1114	160	-6.3	90	-	"	
"	1115	170	-6.5	90	-	"	
"	1116	180	-6.3	100	-	"	Dense Zm, no Rm evident.
"	1118	190	-6.0	80	20	"	Small amount Rm mixed with Zm.
"	1120	200	-6.4	60	10	"	
"	1130	210	-6.6	60	-	"	200-210m scattered patches of dense Rm.
"	1132	220	-7.0	70	-	"	
"	1134	230	-7.3	60	-	"	
"	1135	240	-7.5	80	10	"	

(continued)

APPENDIX D (continued)

TABLE D3 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-15-78	1137	250	- 7.9	70	-	Fine Sand	Dense Zm, no Rm evident in vicinity.
"	1138	260	- 8.8	70	-	"	
"	1140	270	- 7.9	70	-	"	
"	1142	280	- 8.7	50	-	"	Abundant Zm all along this section of transect.
"	1143	290	- 8.2	50	-	"	
"	1144	300	- 8.1	20	-	"	No Rm last 50m.
"	1150	310	- 7.5	30	-	"	
"	1152	320	- 7.8	20	-	"	
"	1154	330	- 8.3	50	-	"	
"	1155	340	- 8.8	trace	-	"	330-340m bare sand with scattered Zm.
"	1156	350	- 9.4	10	-	"	
"	1157	360	-10.1	trace	-	"	Bare sand with scattered Zm.
"	1158	370	-10.8	-	-	"	
"	1159	380	-11.0	-	-	"	
"	1200	390	-11.3	-	-	"	
"	1201	400	-12.1	-	-	"	No Zm observed last 20m, transect ended.

[1] @ 1020 hrs. salinity = 18.0 ppt

[2] EDST

[3] Bearing of 75° mn

[4] From calculated Mean Low Water (See Text)

[5] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D4: BROWN'S BAY-TRANSECT B[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-15-78	1250	0	- .6	-	-	Peat	Eroded peat blocks at edge of marsh.
"	1251	10	-2.5	trace	60	Fine Sand	Scattered patches Rm.
"	1252	20	-2.6	1	70	"	20-30m scattered mixed stands.
"	1253	30	-2.7	-	-	"	Scattered mixed stands, Rm dominant.
"	1254	40	-3.8	20	70	"	
"	1255	50	-5.2	50	20	"	
"	1256	60	-5.1	50	20	"	40-60m detrital Zm and Rm abundant on bottom.
"	1257	70	-4.8	70	10	"	
"	1258	80	-4.7	50	20	"	Zm dominates but mixed with Rm.
"	1259	90	-4.6	60	20	"	
"	1300	100	-5.1	70	30	"	Rm abundant but mostly Zm.
"	1308	110	-4.9	70	30	"	
"	1309	120	-4.7	50	30	"	110-140m Rm tall and flowering.
"	1311	130	-5.0	50	50	"	
"	1312	140	-5.2	40	60	"	
"	1314	150	-5.5	60	40	"	
"	1315	160	-5.5	60	40	"	
"	1316	170	-5.5	50	50	"	150-200m dense, mixed stands of grasses.
"	1318	180	-5.4	50	50	"	
"	1319	190	-5.0	20	80	"	
"	1320	200	-5.5	70	30	"	

(continued)

APPENDIX D (continued)

TABLE D4 (continued)

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-15-78	1330	210	-5.8	20	80	Fine Sand	
"	1332	220	-5.4	40	60	"	
"	1334	230	-5.8	50	50	"	
"	1335	240	-6.3	60	40	"	Dense mixed stands of grasses.
"	1336	250	-6.5	10	90	"	
"	1337	260	-6.5	20	80	"	
"	1338	270	-6.6	70	30	"	
"	1339	280	-6.3	50	50	"	
"	1340	290	-5.7	60	40	"	
"	1342	300	-5.9	40	60	"	
"	1355	310	-5.8	80	-	"	Small raised hummock of Zm, adjacent bottom -6.3dm.
"	1357	320	-5.9	70	30	"	
"	1359	330	-7.1	40	-	"	Patches of Rm mixed with large patches of sand.
"	1401	340	-7.3	30	-	"	
"	1402	350	-7.2	20	-	"	
"	1404	360	-7.3	-	-	"	No vegetation evident.
"	1405	370	-7.6	1	-	"	
"	1407	380	-8.1	30	-	"	
"	1409	390	-9.2	40	-	"	Scattered clumps of Zm.

(continued)

APPENDIX D (continued)

TABLE D4 (continued)

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-15-78	1410	400	-10.6	-	-	Bare Sand	End of vegetation 395m.

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[1] @ 1430 hrs. salinity = 17.7 ppt
water temperature = 29.5°C

[2] EDST

[3] Bearing of 75°mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[5] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D5: WARE NECK-TRANSECT A[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm $(0.1m^2)$	% Rm $(0.1m^2)$	Bottom Type	Observations[5]
8-16-78	1045	0	+2.8	-	-	Fine Sand	Begin transect at sand beach.
"	1146	10	+ .4	-	-	"	First patch of Rm at 12m.
"	1148	20	-0.6	-	100	"	20-30m patches of Rm 1-2m in diameter.
"	1050	30	- .4	-	20	"	
"	1052	40	-1.4	-	90	"	Detrital Zm on bottom.
"	1054	50	-1.3	-	60	"	40-50m Rm fairly uniform coverage.
"		54	- .3	-	-		Bare sandbar.
"	1056	60	- .8	-	50	"	
"	1057	70	-2.1	-	80	"	60-70m dense Rm.
"	1052	80	-1.3	-	30	"	70-80m bare sand.
"	1059	90	-2.1	-	100	"	
"	1100	100	-4.4	5	95	"	90-100 dense Rm.
"	1110	110	-5.1	50	50	"	100-110 abundant Zm and Rm.
"	1114	120	-4.6	60	40	"	
"	1115	130	-2.7	-	-	"	
"		132	-2.3	-	-	"	122-140m sandbar no vegetation present.
"		134	-2.3	-	-	"	
"		136	-2.7	-	-	"	
"		138	-3.1	-	-	"	
"	1118	140	-3.9	-	-		
"		142	-4.6	90	10	"	
"	1121	150	-6.7	80	89	"	142-150 Zm dominates.
"	1123	160	-6.5	85	15	"	150-160 dense Rm mixed with Zm.
"	1124	164	-5.7	-	-	"	Grass ends, rapid rise to bar.

(continued)

TABLE D5 (continued)

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-16-78	1125	170	- 3.8	-	-	Fine Sand	Sandbar.
"	1127	180	- 5.2	5	-	"	170-180 scattered, sparse Zm.
"	1130	190	- 7.6	60	-	"	Dense Zm on slope of sandbar.
"	1131	194	- 8.1	-	-	"	Zm ends.
"	1131	196	- 7.7	-	-	"	
"	1131	198	- 6.8	-	-	"	Bare sandbar.
"	1132	200	- 4.4	-	-	"	Bottom rapidly rises at sandbar, no Zm or Rm.
"	1140	202	- 4.7	-	-	"	
"	1141	204	- 3.9	-	-	"	
"	1142	206	- 3.4	-	-	"	Top of sandbar.
"	1143	208	- 3.4	-	-	"	
"	1144	210	- 3.9	-	-	"	
"		214	- 5.4	5	-	"	Scattered Zm begins.
"	1146	220	- 8.7	80	trace	"	220-230m small trace of Rm mixed with Zm.
"	1148	230	-10.1	60	-	"	
		236	- 9.7	-	-	"	Zm ends.
"	1150	240	- 9.0	-	-	"	Scattered Zm in vicinity.
"	1151	246	- 7.1	-	-	"	Bare sand.
"	1152	250	- 5.0	-	-	"	Bare sand.
"	1152	252	- 4.5	-	-	"	
"	1153	254	- 4.0	-	-	"	Top of sandbar.
"	1153	256	- 4.1	-	-	"	
"	1153	258	- 4.6	-	-	"	
"	1154	260	- 5.4	20	-	"	260-270 Zm in scattered small patches.

(continued)

APPENDIX D (continued)

TABLE D5 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-16-78	1155	264	- 8.1	-	-	Fine Sand	
"	1156	270	- 9.1	70	-	"	
"	1157	280	- 9.8	40	-	"	
"	1158	290	- 8.9	60	-	"	
"		292	- 9.0	-	-	"	Zm ends.
"		296	- 8.2	-	-	"	Bare sand.
"	1200	300	- 8.2	-	-	"	Bare sand no vegetation.
"	1210	302	- 7.1	-	-	"	
"	1210	304	- 6.1	-	-	"	Rapid rise in bottom to sandbar.
"	1211	306	- 5.9	-	-	"	
"	1211	308	- 5.5	-	-	"	Top of sandbar.
"	1212	310	- 6.1			"	
"		314	- 7.0			"	314-330 scattered patches of Zm.
"	1213	320	- 9.5	50	-	"	
"	1214	330	-10.9	30	-	"	Patches of Zm less than 1m diameter approximately 20% of bottom covered.
"	1215	340	-11.3	-	-	"	Scattered patches of Zm. approximately 10% of bottom covered.
"	1219	350	-11.2	-	-	"	Scattered small patches of Zm approximately 1% of bottom covered.
"	1221	360	- 9.9	-	-	"	No vegetation in vicinity.
"	1223	370	- 7.6	-	-	"	Sandbar.

(continued)

APPENDIX D (continued)

TABLE D5 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-16-78	1225	380	- 8.2	-	-	Fine Sand	
"	1227	390	-11.4	-	-	"	
"	1230	400	-14.6	-	-	"	No vegetation last 40m, transect ended.

---

[1] @ 1030 hrs. salinity = 17.6 ppt
water temperature = 30.0°C

[2] EDST

[3] Bearing of 100° mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[4] Zm = *Zostera marina*
Rm = *Ruppia maritima*

TABLE D6: WARE NECK-TRANSECT B[1]

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
8-16-78	1336	0	- .6	-	-	Fine Sand	Transect begins at edge of marsh.
"	1337	10	-1.7	-	-	Silty Sand	Thick detrital Rm on bottom.
"	1338	20	-2.0	-	50	Fine Sand	16m Rm begins.
"	1339	30	-2.2	-	70	"	Large patches Rm with areas of bare sand between.
"	1340	40	-2.3	-	90	"	Dense Rm covers most of bottom.
"	1341	50	-3.1	-	50	"	
"	1342	60	-2.7	-	100	"	Middle of a large patch of Rm.
"		66	-3.3	-	-	"	Area of bare sand.
"	1344	70	-3.5	40	60	"	68m Zm observed for first time.
"	1346	80	-3.8	1	99	"	
"	1348	90	-4.2	5	95	"	Rm continues very abundant.
"	1350	100	-4.3	20	80	"	Mixed stand, Rm dominates.
"	1400	110	-5.4	50	50	"	100-110 Zm and Rm abundant.
"	1402	120	-5.9	80	5	"	120-130 Rm more abundant than Zm in vicinity.
"	1403	130	-4.7	60	40	"	
"	1404	140	-5.8	70	30	"	Small areas of dense Rm but Zm dominates.
"	1406	150	-6.1	50	30	"	
"	1407	160	-6.0	10	90	"	Large patch Rm with some Zm.
"	1408	170	-5.2	40	60	"	
"	1410	180	-4.4	60	40	"	Zm dominates in vicinity.
"	1411	190	-5.5	90	10	"	

(continued)

APPENDIX D (continued)

TABLE D6 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-16-78	1412	200	-7.3	90	trace	Fine Sand	
"	1420	210	-6.8	80	10	"	210-220m grasses patchy with large areas bare sand.
"	1422	220	-7.0	70	20	"	
"	1425	230	-7.3	80	-	"	230-240m small (1-3m) clumps Zm.
"	1427	240	-7.4	15	-	"	240-250 mostly bare sand scattered Zm.
"	1428	250	-7.8	20	-	"	
"	1430	260	-5.9	10	60	"	Rise in bottom with large patch of mostly Rm.
"	1432	270	-7.2	20	-	"	No Rm observed in vicinity.
"	1434	280	-7.8	-	-	"	Scattered Zm in vicinity.
"	1435	290	-8.2	5	-	"	
"	1427	300	-6.8	20	-	"	No Rm observed.
"	1445	310	-6.7	10	-	"	310-320m scattered Zm in small patches.
"	1446	320	-9.0	10	-	"	
"	1447	330	-9.4	trace	-	"	Sparse Zm in vicinity.
"	1448	340	-7.4	-	-	"	
"	1449	350	-9.3	-	-	"	
"	1450	360	-9.7	trace	-	"	Very sparse Zm.
"	1451	370	-7.7	-	-	"	No vegetation observed, slight rise in bottom.
"	1452	380	-8.7	-	-	"	
"	1453	390	-9.7	-	-	"	

(continued)

APPENDIX D (continued)

TABLE D6 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm $(0.1m^2)$	% Rm $(0.1m^2)$	Bottom Type	Observations[5]
8-16-78	1454	400	-9.2	-	-	Fine Sand	Bare sand, no vegetation last 40m.

[1] @ 1320 hrs. salinity = 17.3 ppt
water temperature = 30.0°C

[2] EDST

[3] Bearing of 180° mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[5] Zm = *Zostera marina*
Rm = *Ruppia maritima*

APPENDIX D (continued)

TABLE D7: EAST RIVER-TRANSECT A[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-17-78		-8	+5.8	-	-	Fine Sand	Shoreline behind marsh has eroded, falling trees etc.
"		-6	+2.9	-	-	"	
"		-4	+2.0	-	-	"	
"		-2	+1.5	-	-	"	
"	1037	0	+1.1	-	-	"	Transect begins at edge of marsh fringe.
"	1039	10	+ .2	-	-	Coarse Sand	
"	1041	20	- .4	-	-	"	Detrital Rm on bottom.
"	1042	30	- .6	-	-	"	Detrital Rm on bottom.
		34	- .7	-	trace	"	Live Rm begins, scattered plants only.
"	1044	40	- .9	-	-	"	Some Rm in vicinity.
"	1045	50	-1.0	-	-	"	40-50m, no Rm observed.
"	1046	60	- .4	-	-	"	Isolated patches and individual plants of Rm.
"	1048	70	-1.8	-	5	"	66-69m large patch Rm.
"	1050	80	-1.7	-	100	"	Dense, short Rm begins.
"	1052	90	-2.0	-	80	"	80-90m large patches Rm.
"	1055	100	-2.3	-	100	"	
"	1100	110	-2.2	-	-	"	104-110m bare sand. 110-120m patches Rm in vicinity. 116m Zm begins but very sparse.
"	1102	120	-1.8	-	100	"	
"	1105	130	-2.6	-	100	"	Large patches Rm.
"	1107	140	-2.5	-	100	"	
"	1110	150	-3.4	1	99	"	150-160m dense Rm.
"	1112	160	-4.4	1	99	"	Rm dense, scattered Zm.

(continued)

APPENDIX D (continued)

TABLE D7 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
8-17-78	1114	170	-4.7	1	99	Coarse Sand	170-180m Zm increases in abundance.
"	1115	180	-5.4	40	60	"	
"	1116	190	-5.9	40	60	Fine Sand	180-210m mixed stands flowering Rm and Zm.
"	1118	200	-6.3	70	30	"	Rm not flowering.
"	1126	210	-6.4	80	20	"	Dense Zm scattered Rm.
"	1130	220	-6.5	70	30	"	
"	1132	230	-6.7	80	5	"	
"	1135	240	-7.1	90	trace	"	Rm and Zm mixed, scattered clumps.
"	1137	250	-7.0	70	5	"	Rm short and not flowering.
"	1140	260	-7.0	30	-	"	No Rm 250-260m, Zm not dense.
"	1142	270	-7.0	5	-	"	Sparse Zm 260-270m.
"	1144	280	-7.2	5	-	"	Sparse Zm.
"	1145	290	-7.5	-	-	"	280-300m scattered Zm turions 2-5cm high.
"	1146	300	-7.3	-	-	"	
"	1147	310	-7.2	-	-	"	Last Zm at 305m, then bare sand.

---

[1] @ 1020 hrs. salinity = 18.6 ppt
water temperature = 29°C

[2] EDST

[3] Bearing of 245° mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[5] Zm = *Zostera marina*
Rm = *Ruppia maritima*

APPENDIX D (continued)

TABLE D8: EAST RIVER-TRANSECT B[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
8-17-78	1255	0	- .5	-	-	Fine Sand	Begin transect at edge of marsh.
"	1256	10	-1.1	-	-	"	Abundant detrital Rm on bottom.
"	1257	20	- .8	-	30	"	
"	1258	30	-1.7	-	-	"	20-140m large patches of Rm, 5-10m in diameter.
"	1259	40	-2.9	-	-	"	Area of sand between patches of Rm.
"	1300	50	-2.6	-	50	"	
"	1301	60	-2.2	-	100	"	Dense short Rm.
"	1302	70	-2.5	-	100	"	
"	1303	80	-3.0	-	90	"	
"	1304	90	-3.3	-	100	"	Abundant epiphytic algae mixed with Rm last 50m.
"	1305	100	-3.5	-	100	"	
"	1314	110	-3.5	-	100	"	Dense flowering Rm.
"	1316	120	-3.4	-	100	"	
"	1320	130	-4.5	-	-	"	
"	1322	140	-4.5	trace	80	"	132m very sparse Zm begins.
"	1323	150	-3.8	10	-	"	Small patch Zm, Rm in vicinity.
"	1324	160	-4.2	5	80	"	
"	1325	170	-3.7	-	-	"	Zm present 160-170m 1-5% of bottom covered.
"	1326	180	-4.7	-	80	"	
"	1327	190	-5.9	30	70	"	190-200m small patches of Rm and Zm with bare sand between.

(continued)

APPENDIX D (continued)

TABLE D8 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
8-17-78	1329	200	-4.9	10	90	Fine Sand	
"	1342	210	-6.9	30	30	"	Large clumps of mixed grasses.
"	1343	220	-7.1	40	60	"	
"	1345	230	-7.3	40	5	"	230-240m sparse patches with, Zm dominant.
"	1347	240	-7.9	-	-	"	
"	1348	250	-8.4	5	-	"	250-260m mostly sand with sparse Zm.
"	1349	260	-8.9	1	-	"	
"	1350	270	-9.0	10	-	"	Sparse Zm.
"	1352	280	-9.2	-	-	"	Bare area between patches of sparse Zm.
"	1354	290	-8.5	10	-	"	
"	1355	300	-8.0	60	40	"	300-310m scattered small clumps Zm with some Rm.
"	1404	310	-8.3	5	-	"	
"	1405	320	-8.2	trace	-	"	320-340m sparse Zm.
"	1406	330	-8.2	"	-	"	
"	1407	340	-8.0	"	-	"	No Zm 340-350m.
"	1408	350	-7.0	-	-	"	
"	1409	360	-7.3	-	-	"	Bare sandbar.
"	1410	370	-7.4	-	-	"	
"	1412	380	-7.8	-	-	"	Bare sand no vegetation observed last 30m.
"	1414	390	-8.3	-	-	"	

(continued)

APPENDIX D (continued)

TABLE D8 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
8-17-78	1415	400	-8.8	-	-	Fine Sand	Depth continues to increase, no vegetation, transect ended.

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[1] @ 1250 hrs. salinity = 17.7 ppt
water temperature 32°C

[2] EDST

[3] Bearing of 240° mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.3 dm

[5] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D9: HORN HARBOR-TRANSECT A[1]

Date	Time[2]	Distance[3] from shoreline (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-6-78	1010	0	+5.9	-	-	Peat	Adjacent to fringe marsh, eroded peat blocks on bottom.
"	1012	10	+ .3	-	-	Fine Sand	
"	1015	20	+ .7	20	60	"	Scattered detrital Rm along bottom.
"	1016	30	- .8	40	-	"	
"	1017	40	-2.3	30	10	"	Mixed stands of Zm and Rm.
"	1022	50	-2.4	50	20	"	
"	1024	60	-2.1	10	-	"	40-60m scattered patches Zm, bare sand between patches.
"	1026	70	-1.3	10	-	"	No Rm observed in vicinity.
"	1028	80	-2.7	50	-	"	60-90m scattered patches Zm some detrital material.
"	1030	90	-3.7	40	-	"	
"	1032	100	-3.7	40	-	"	
"	1052	110	-3.5	40	-	"	
"	1054	120	-3.5	30	-	"	Zm only, no Rm.
"	1056	130	-3.5	60	-	"	
"	1058	140	-3.6	40	-	"	
"	1100	150	-3.9	-	-	"	140-150m Zm less dense than inshore areas.
"	1103	160	-3.7	30	-	"	150-160m scattered patches Zm.
"	1105	170	-3.7	20	-	"	Scattered patches Zm.
"	1107	180	-4.5	-	-	"	Scattered patches Zm in vicinity.
"	1109	190	-3.8	40	-	"	Large patch Zm.
"	1112	200	-3.7	30	-	"	
"	1125	210	-3.6	10	-	"	Sparse Zm throughout area.

(continued)

APPENDIX D (continued)

TABLE D9 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[5]
9-6-78	1127	220	-3.2	30	-	Fine Sand	
"	1130	230	-3.0	50	-	"	
"	1132	240	-1.2	10	-	"	Sandbar with sparse Zm.
"	1134	250	-2.7	5	-	"	
"	1136	260	-2.9	25	-	"	
"	1138	270	-3.7	30	-	"	Zm in scattered patches.
"	1140	280	-3.5	-	-	"	Zm present last 10m.
"	1142	290	-4.7	-	-	"	280-290m Zm very sparse.
"	1145	300	-4.0	-	-	"	
"	1220	310	-4.2	-	-	"	
"	1222	320	-5.2	-	-	"	
"	1224	330	-2.2	-	-	"	
"	1225	333	-1.6	50	-	"	Large patch of Zm.
"	1227	340	- .6	-	-	"	Sand bar with no Zm.
"	1229	350	-3.3	-	-	"	Zm in vicinity but very sparse.
"	1231	360	-4.0	-	-	"	
"	1233	370	-3.1	-	-	"	
"	1235	380	-3.8	-	-	"	No Zm last 20m.
"	1238	390	-4.3	trace	-	"	Several Zm turions.
"	1240	400	-4.6	-	-	"	No Zm observed in vicinity.

[1] @ 940 hrs. salinity = 17.5 ppt
water temperature = 24.5°C

[2] EDST

[3] Bearing of 120° mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tidal range = 7.0 dm

[5] Zm = Zostera marina
Rm = Ruppia maritima

TABLE D10: HORN HARBOR-TRANSECT B[1]

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-7-78	1025	0	+2.4	-	-	Peat	Edge of marsh, peat blocks.
"	1028	10	- .1	-	-	Silty Sand	Silty sand bottom no veg. last 10m.
"	1031	20	- .1	-	-	"	Continue no vegetation.
"	1033	30	-2.4	10	-	"	Fine sand & silt bottom, small patch of Zm.
"	1036	40	-3.8	-	-	Silt	
"	1039	50	-4.6	-	-	"	Large amounts of detrital Zm and Rm on bottom.
"	1040	60	-4.7	-	-	"	
"	1042	70	-4.7	-	-	"	Detrital Zm and Rm on bottom.
"	1045	80	-4.8	-	-	"	
"	1048	90	-4.9	1	-	"	Several sprigs of Zm.
"	1050	100	-4.6	trace	-	"	
"	1059	110	-4.5	20	-	"	Detrital Rm on bottom.
"	1100	120	-4.1	10	-	"	Detrital Zm and Rm on bottom.
"	1102	130	-3.3	20	-	"	
"	1104	140	-2.8	5	-	"	Less detrital Zm & Rm.
"	1105	150	-1.7	40	trace	Silty Sand	
"	1107	160	-1.0	50	20	"	
"	1109	170	- .3	70	10	Fine Sand	
"	1111	180	+ .2	-	-	"	170-180m sparse Zm.
"	1113	190	+ .5	-	-	Coarse Sand	Sand bar adjacent to marsh island.
"	1115	200	+ .8	-	-	"	
"	1127	210	+ .9	-	-	"	
"	1129	220	+1.1	-	-	Fine Sand	Scattered Zm sprigs 210-220m.

(continued)

TABLE D10 (continued)

Date	Time^2	Distance^3 from shore-line (m)	Elevation^4 (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations^5
9-7-78	1130	230	+ .7	-	-	Fine Sand	
"	1133	240	+ .7	-	-	"	
"	1135	250	+ .6	40	20	"	Large patch of mixed Zm and Rm.
"	1137	260	+ .1	30	10	"	
"	1139	270	.0	30	10	"	Grass patchy in vicinity.
"	1140	280	- .1	5	trace	"	Trace of Rm with sparse Zm.
"	1150	290	+1.0	-	-	"	Bare Sand.
"	1152	300	+1.6	-	-	"	Shallow sandbar.
"	1215	310	+1.3	-	-	"	
"	1217	320	+ .4	-	-	"	310-320m sparse Zm and Rm.
"	1219	330	-1.4	50	-	"	
"	1221	340	-2.4	20	-	"	
"	1222	350	-2.5	30	-	"	Zm in clumps with bare sand between.
"	1223	360	-2.8	60	-	"	
"	1224	370	-3.0	20	-	"	
"	1226	380	-3.6	60	-	"	
"	1227	390	-3.4	70	-	"	
"	1242	400	-3.5	40	-	"	
"	1244	410	-4.2	40	-	"	
"	1245	420	-4.1	60	-	"	
"	1246	430	-3.4	30	-	"	No Rm observed last 100m.
"	1247	440	-3.4	50	-	"	
"	1248	450	-3.8	5	-	"	Zm patchy in vicinity.
"	1249	460	-3.4	80	-	"	
"	1251	470	-2.7	50	-	"	Large patches of Zm.
"	1253	480	-2.7	30	-	"	

(continued)

APPENDIX D (continued)

TABLE D10 (continued)

Date	Time[2]	Distance[3] from shore-line (m)	Elevation[4] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[5]
9-7-78	1254	490	-2.9	30	-	Fine Sand	
"	1300	500	-3.4	70	-	"	Zm only no Rm.
"	1306	510	-4.4	20	-	"	
"	1307	520	-4.4	-	-	"	Bare sand Zm scattered clumps.
"	1308	530	- .8	-	-	"	Rapid rise in bottom due to sandbar.
"	1312	540	-1.4	-	-	"	
"	1315	550	-4.0	30	-	"	Continued scattered patches of Z
"	1317	560	-4.6	20	-	"	
"	1319	570	-4.0	-	-	"	Bare sand.
"	1320	580	-4.2	-	-	"	Bare sand.
"	1321	590	-2.5	-	-	"	
"	1323	600	-1.3	-	-	"	Sandbar with no Zm or Rm observed.
"	1325	610	-5.2	-	-	"	
"	1327	620	-5.6	-	-	"	Depth continues to increase, end transect.

[1] @ 955 hrs. salinity = 24.5 ppt
water temperature = 24.5°C

[2] EDST

[3] Bearing of 120° mn

[4] From calculated Mean Low Water (See Text)
N.O.S. mean tide range = 7.0 dm

[5] Zm = *Zostera marina*
Rm = *Ruppia maritima*

APPENDIX D (continued)

TABLE D11: VAUCLUSE SHORES-TRANSECT A1

Date	Time[1]	Distance[2] from shore-line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[4]
7-31-78	1055	0	- .7	-	-	Fine Sand	Bare sand with oyster shells.
"	1057	10	- 2.0	-	50	"	Rm begins at 6m.
"	1059	20	- 1.7	-	10	"	
"	1101	30	- 2.1	-	50	"	
"	1103	40	- 2.1	-	70	"	
"	1105	50	- 2.8	-	100	"	Rm dense and flowering.
"	1107	60	- 2.5	-	90	"	
"	1109	70	- 3.0	trace	90	"	Only one or two Zm turions per $0.1m^2$.
"	1111	80	- 3.2	trace	95	"	
"	1113	90	- 3.4	trace	99	"	
"	1115	100	- 3.7	trace	95	"	
"	1120	110	- 3.8	trace	90	"	
"	1122	120	- 3.8	5	95	"	
"	1124	130	- 4.9	trace	75	"	Small depression in bottom.
"	1125	140	- 3.9	trace	90	"	
"	1127	150	- 4.6	20	50	"	Increased abundance of Zm last 10m.
"	1129	160	- 4.7	10	80	"	
"	1131	170	- 4.1	10	85	"	
"	1133	180	- 4.4	5	95	"	
"	1135	190	- 4.6	15	80	"	
"	1136	200	- 4.8	40	60	"	
"	1140	210	- 5.4	40	60	"	
"	1142	220	- 5.6	80	10	"	Zm very abundant last 10m.
"	1144	230	- 5.6	90	10	"	
"	1146	240	- 5.4	60	30	"	

(continued)

APPENDIX D (continued)

TABLE D11 (continued)

Date	Time[1]	Distance[2] from shore-line (m)	Elevation[3] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[4]
7-31-78	1148	250	- 5.2	60	30	Fine Sand	
"	1151	260	- 5.8	50	50	"	
"	1153	270	- 6.1	70	20	"	Continued abundant Zm with Rm mixed throughout.
"	1155	280	- 6.0	70	20	"	
"	1157		- 6.0	80	10	"	
"	1159	300	- 6.0	70	trace	"	
"	1200	310	- 5.9	50	40	"	
"	1202	320	- 5.8	50	-	"	
"	1204	330	- 5.5	50	10	"	
"	1205	340	- 5.4	40	10	"	
"	1207	350	- 5.4	10	70	"	
"	1209	360	- 4.9	40	40	"	Mixed stands of Zm and Rm.
"	1210	370	- 5.3	40	60	"	
"	1212	380	- 5.5	40	20	"	
"	1214	390	- 5.0	40	10	"	
"	1215	400	- 5.9	50	-	"	
"	1216	410	- 3.8	-	50	"	Slight rise in bottom near channel.
"	1217	420	-12.2	-	-	"	Rapid dropoff at channel.

[1] EDST

[2] Bearing of 190° mn

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4 dm

[4] Zm = Zostera marina
Rm = Ruppia maritima

TABLE D12: VAUCLUSE SHORES-TRANSECT A

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-25-78	1040	0	+ .1	-	-	Fine Sand		Begin transect at small marsh island.
"	1041	10	- 1.9	-	-	"		Area of bare sand just off marsh island.
"	1043	20	- 2.3	-	-	"		
"	1044	26	- 2.6	-	5	"		Patchy Rm begins.
"	1045	30	- 3.0	-	-	"		
"	1047	32	- 3.1	-	100	"		Dense Rm no Zm observed.
"	1049	40	- 3.4	-	100	"		
"	1050	48-50	- 5.5	-	-	"		Bare area.
"	1052	52	- 4.8	-	-	"		Bare area.
"	1054	56	- 4.3	-	5	"		Small patch of Rm.
"	1055	60	- 3.7	-	95	"		Scattered Zm mixed with Rm.
"	1058	70	- 4.0	-	40	"		No Zm between 60-70m
"	1101	70-76	- 4.0	-	40	"		Very patchy Rm.
"	1105	80	- 4.1	2	95	"		
"	1108	90	- 6.4	3	97	"		Dense Rm.
"	1110	100	- 6.2	40	60	"	A2	Dense cover by mixed stand of grasses.
"	1134	110	- 4.3	15	85	"		Continued dense coverage by mixed grasses.
"	1138	120	- 5.3	15	85	"		
"	1142	130	- 6.3	5	85	"		
"	1145	140	- 6.2	5	95	"		
"	1147	150	- 6.2	5	60	"	A3	Rm dominates throughout area.

(continued)

APPENDIX D (continued)

TABLE D12 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-25-78	1155	160	- 5.4	trace	85	Fine Sand		
"	1157	170	- 5.6	5	70	"		
"	1200	180	- 6.2	5	95	"		
"	1205	190	- 6.1	30	60	"		
"	1210	200	- 6.7	25	75	"	A4	
"	1225	210	- 7.0	20	80	"		
"	1230	220	- 5.5	-	5	"		Open sand with sparse Rm.
"	1235	230	- 7.9	20	50	"		
"	1237	240	- 8.1	15	55	"		
"	1240	250	- 7.6	80	20	"	A5	
"	1247	260	- 7.0	-	60	Silty Sand		
"	1250	270	- 5.7	1	95	Fine Sand		Small bar with mostly Rm.
"	1252	280	- 6.0	10	90	"		Flowers abundant on Rm.
"	1255	290	- 6.6	30	60	"		
"	1300	300	- 7.0	90	10	"	A6	
"	1500	310	- 7.4	20	80	"		Zm abundant but Rm dominant.
"	1506	320	- 8.0	90	10	"		
"	1509	330	- 8.6	45	40	"		
"	1512	340	- 9.1	50	30	"		
"	1530	350	- 8.6	45	45	"	A7	
"	1540	360	- 9.2	90	-	"		Scattered patches dense Rm in vicinity.
"	1544	370	- 9.3	70	30	"		
"	1548	380	- 9.3	90	10	"		Dense Zm, Scattered Rm.

(continued)

APPENDIX D (continued)

TABLE D12 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-25-78	1549	390	- 9.0	90	10	Fine Sand		
"	1550	400	- 8.9	95	5	"	A8	
7-26-78	920	400	- 8.9	95	5	"		
"	921	410	- 9.9	50	10	"		Rm sparse Zm dominant.
"	921	410-20	- 9.8	-	-	"		Patchy Zm, Rm in these patchy areas only.
"	922	420	- 9.7	50	50	"		
"	923	430	-10.4	70	-	"		No Rm observed.
"	924	440	- 9.6	90	5	"		
"	925	450	-10.1	75	-	"	A9	450-60 Zm abundant no Rm observed.
"	930	460	-10.2	50	-	"		
"	932	470	-10.5	90	-	"		
"	934	480	-10.5	95	-	"		
"	935	490	-11.0	75	-	"		
"	940	500	-10.7	80	-	"	A10	
"	950	510	-10.0	95	-	"		
"	952	520	-10.3	40	20	"		Patchy area.
"	954	530	-10.1	90	-	"		530-540 Zm dense, almost no Rm.
"	957	540	-10.3	80	-	"		
"	1000	550	-10.4	90	-	"	A11	
"	1002	560	-10.4	50	-	"		
"	1003	570	-10.4	75	-	"		
"	1004	580	- 9.9	75	-	"		
"	1005	590	- 9.3	90	-	"		Rm observed in vicinity.
"	1010	600	- 9.1	80	-	"	A12	
"	1015	610	- 8.5	100	-	"		

(continued)

APPENDIX D (continued)

TABLE D12 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Sample #	Observations[4]
7-26-78	1016	620	- 9.5	5	-	Fine Sand		
"	1018	630	- 8.4	25	25	"		646 abundant flowering Rm.
"	1019	640	- 7.2	50	-	"		
"	1020	650	- 7.1	85	5	"	A13	620-650 Zm short
"	1025	660	- 7.7	80	-	"		
"	1027	670	- 8.0	90	-	"		
"	1030	680	- 8.6	75	-	"		680-690 no Rm observed.
"	1032	690	- 9.1	75	-	"	A14	
"	1035	700	-10.2	90	-	"		Edge of bar; bare sand.
"	1040	710	-11.0	-	-	"		
"	1042	720	- 5.5	-	-	"		
"	1044	730	- 3.5	-	-	"		Scattered Rm on bar very sparse coverage. Transect ended.
"	1045	740	- 2.7	-	trace			

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[1] EDST

[2] Bearing of 290° mn

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4 dm

[4] Zm = *Zostera marina*
Rm = *Ruppia maritima*

APPENDIX D (continued)

TABLE D13: VAUCLUSE SHORES-TRANSECT B

Date	Time^1	Distance^2 from shore line (m)	Elevation^3 (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Sample #	Observations^4
7-26-78	1535	0	+ .8	-	80	Fine Sand		Edge of fringing marsh.
"	1534	10	+ .4	-	-	"		Abundant Zm & Rm detritus on bottom.
"	1533	20	+ .4	-	50	"		
"	1532	30	+ .5	-	100	"		Dense cover by Rm.
"	1531	40	+ .3	-	100	"		
"	1530	50	+ .7	-	100	"		
"	1525	60	0.0	-	100	"	B11	Continued dense cover by Rm.
"	1524	70	- .5	-	100	"		
"	1524	80	- .4	-	100	"		
"	1522	90	- .6	-	100	"		All Rm covered with epiphytic algae.
"	1520	100	- .7	-	100	"		
"	1515	110	- .7	-	100	"	B10	Dense flowering Rm.
"	1513	120	- .7	-	100	"		
"	1512	130	- .7	-	100	"		
"	1511	140	- .8	-	100	"		
"	1510	150	- .8	-	100	"		
"	1506	160	- .9	-	50	"	B9	
"	1505	170	- .9	-	90	"		
"	1504	180	- .6	-	20	"		Rm becoming sparse.
"	1503	190	- .8	-	20	"		
"	1502	200	- .6	-	-	"		Generally bare sand.
"	1500	210	- .6	-	-	"		
"	1459	220	- .8	-	-	"		Bare sand.
"	1458	230	- .5	-	-	"		

(continued)

APPENDIX D (continued)

TABLE D13 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-26-78	1457	240	- .7	-	-	Fine Sand		
"	1455	250	- .5	-	20	"		Small patch of Rm.
"	1445	260	- .7	-	-	"		
"	1440	270	- .8	-	-	"		
"	1437	280	- 1.0	-	15	"		
"	1436	290	- .7	-	100	"		
"	1435	300	- 1.3	5	10	"		Small patch of mixed grasses.
"	1434	300	- 1.3	-	15	"		
"	1432	320	- 2.3	-	15	"		
"	1430	330	- 2.4	-	50	"		
"	1428	340	- 2.4	-	80	"		300-330m Zm very sparse, mostly Rm.
"	1425	350	- 2.4	-	40	"		
"	1420	360	- 2.5	-	100	"	B8	Dense Rm.
"	1418	370	- 2.9	-	90	"		
"	1417	380	- 3.4	-	98	"		
"	1416	390	- 3.5	5	95	"		
"	1415	400	- 3.8	-	100	"		340-370m Rm flowering.
"	1410	410	- 4.2	90	-	"	B7	Large stand of Zm.
"	1408	420	- 4.5	40	30	"		
"	1407	430	- 4.9	90	10	"		Zm dominated but mixed with Rm.
"	1406	440	- 6.0	30	-	"		
"	1405	450	- 6.1	100	-	"		Dense Zm.
"	1230	460	- 7.1	100	trace	"	B6	A few strands of Rm mixed with Zm.
"	1229	470	- 6.5	80	10	"		

APPENDIX D (continued)

TABLE D13 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-26-78	1228	480	- 6.5	90	10	Fine Sand		
"	1227	490	- 7.0	70	30	"		
"	1226	500	- 7.0	70	30	"		
"	1225	510	- 7.6	60	40	"	B5	Rm only at mark otherwise all Zm.
"	1224	520	- 8.0	20	80	"		
"	1222	530	- 8.2	50	50	"		
"	1220	540	- 8.6	100	-	"		
"	1218	550	- 9.2	95	-	"		Scattered short Rm mixed with Zm.
"	1210	560	- 8.7	100	-	"	B4	
"	1208	570	- 8.6	70	30	"		
"	1207	580	- 8.3	95	5	"		
"	1206	590	- 8.9	90	10	"		Grasses in patchy distribution.
"	1205	600	- 9.1	1	99	"		Large stand of flowering Rm.
"	1200	610	- 9.1	90	-	"	B3	
"	1157	620	- 9.9	100	-	"		
"	1155	630	-10.8	90	-	"		130-150m Zm very dense.
"	1153	640	-12.6	80	-	"		
"	1150	650	-10.8	60	-	"		
"	1140	660	- 9.8	80	-	"	B2	
"	1138	670	- 8.8	20	50	"		Rm very short only 3-4 cm tall.
"	1137	680	- 8.5	40	20	"		
"	1136	690	- 9.0	10	-	"		Rm observed in vicinity.
"	1135	700	- 8.2	40	-	"		

(continued)

APPENDIX D (continued)

TABLE D13 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm $(0.1m^2)$	% Rm $(0.1m^2)$	Bottom Type	Sample #	Observations[4]
7-26-78	1130	710	-10.2	95	-	Fine Sand	B1	
"	1128	720	- 9.7	60	-	"		
"	1126	730	- 9.6	80	-	"		Dense Zm, no Rm observed.
"	1124	740	- 4.1	5	-	"		Zm ends at 745m.
"	1122	750	± .4	-	-	"		Beginning of sand bar.
"	1120	760	+ 1.4	-	-	"		Bare sand, transect ended.

[1] EDST

[2] Bearing of 290°m

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4dm

[4] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D14: VAUCLUSE SHORES-TRANSECT C

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm $(0.1m^2)$	% Rm $(0.1m^2)$	Bottom Type	Sample #	Observations[4]
7-25-78	1647	10	-1.2	-	-	Fine Sand		Bare sand just off fringing marsh.
"	1648	12		-	trace	"		Small patch of Rm.
"	1650	20	+ .3	-	-	"		
"	1652	30	+ .3	-	-	"		Patches of Rm in vicinity.
"	1653	40	+ .7	-	20	"		
"	1654	50	+ .4	-	100	"	C1	Dense Rm.
"	1659	60	+ .6	1	30	"		Scattered Zm mixed with Rm.
"	1700	70	+ .4	-	100	"		
"	1704	80	0.0	-	1	"		
"	1708	90	+ .2	-	80	"		
"	1712	100	- .2	-	90	"	C2	Dense Rm.
"	1715	110	+ .2	-	100	"		
"	1717	120	- .2	-	5	"		
"	1720	130	- .2	-	-	"		Area of bare sand, Rm in vicinity.
"	1722	140	- .2	-	10	"		
"	1723	150	- .4	20	40	"	C3	Stand of Zm mixed in area of Rm.
"	1724	160	- .4	-	30	"		
"	1725	170	- .4	-	-	"		
"	1726	180	- .4	-	10	"		160-200m very little Zm.
"	1728	190	- .4	-	60	"		
"	1730	200	- .3	-	50	"	C4	Rm generally short in height.
"	1740	210	0.0	-	100	"		

(continued)

TABLE D14 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-25-78	1742	220	- .5	-	-	Fine Sand		Bare sand but Rm in vicinity.
"	1744	230	- .3	-	70	"		
"	1746	240	-1.1	-	-	"		
"	1748	250	-1.9	-	-	"		Bare sand.
"	1750	260	-2.9	-	99	"		
"	1752	270	-3.1	-	95	"		260-270m some Zm observed mixed with Rm.
"	1754	280	-4.1	-	-	"		
"	1757	290	-2.7	-	-	"		Bare sand.
"	1800	300	-3.0	-	90	"	C5	
"	1815	310	-3.2	2	80	"		
"	1816	320	-3.3	1	-	"		Increased Zm between 310-320m.
"	1818	330	-4.6	40	50	"		322-330m Zm increases in abundance.
"	1819	340	-4.1	20	50	"		
"	1820	350	-4.6	40	30	"	C6	
"	1823	360	-4.3	30	70	"		Dense mixed stands of Zm and Rm.
"	1824	370	-5.1	10	70	"		
"	1825	380	-4.8	20	70	"		Continued dense Rm with Zm.
"	1827	390	-4.7	30	70	"		
"	1830	400	-4.4	1	99	"	C7	
"	1840	410	-5.2	-	100	"		Zm largely absent last 10m.

(continued)

APPENDIX D (continued)

TABLE D14 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Sample #	Observations[4]
7-25-78	1843	420	-5.1	20	80	Fine Sand		
"	1845	430	-5.3	20	80	"		
"	1846	436	-5.5	-	-	"		Rm & Zm extremely patchy.
"	1848	440	-5.5	40	-	"		
"	1850	450	-4.9	15	-	"	C8	Bare sand with small patch of Zm.
"	1855	460	-5.3	30	-	"		
"		468	-	-	-	"		Grass stops, sand bar evident.
"	1856	470	-4.6	-	-	"		Bare sand.
"	1857	480	-2.5	-	100	"		Small patch of Rm on sandbar.
"	1858	490	-2.4	-	-	"		Bare sand, no grass evident in vicinity.
"	1859	500	-2.1	-	-	"		
"	1900	510	-1.9	-	-	"		Transect ended.

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[1] EDST

[2] Bearing of 290° mn

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4 dm

[4] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D15: VAUCLUSE SHORES-TRANSECT D

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-31-78	1430	0	+2.1	-	-	Fine Sand		Bare sand, patchy scattered Rm in vicinity.
"	1431	10	+1.2	-	-	"		
"	1432	20	+1.3	-	-	"		
"	1433	30	+1.9	-	-	"		Scattered Rm.
"	1434	40	+1.4	-	-	"		
"	1435	50	+1.3	-	-	"		Bare sand.
"	1436	60	+ .9	-	-	"		Patchy Rm in vicinity.
"	1437	70	+ .7	-	-	"		
"	1438	80	+ .5	-	50	"		Patch of Rm.
"	1439	90	+ .4	-	-	"		
"	1440	100	+ .7	-	-	"		Bare sand.
"	1445	110	+ .2	-	5	"		Sparse Rm.
"	1446	120	+ .3	-	30	"		
"	1447	130	0.0	-	-	"		Bare sand.
"	1449	140	-2.7	10	50	"		Zm mixed with Rm.
"	1450	150	-3.0	-	40	"		Sparse Rm.
"	1452	160	-2.5	-	-	"		Bare sand with large patches of Rm.
"	1455	170	-1.3	-	-	"		
"	1457	180	-1.1	-	-	"		
"	1459	190	-1.2	-	-	"		
"	1500	200	-1.4	-	5	"	D1	
"	1505	210	-3.2	40	50	"		
"	1507	220	-3.2	trace	90	"		Last 20m Rm dense & flowering.
"	1509	230	-2.5	5	95	"		

(continued)

APPENDIX D (continued)

TABLE D15 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-31-78	1510	240	-2.0	-	100	Fine Sand		
"	1515	250	-2.8	trace	90	"	D2	
"	1520	260	-3.6	70	5	"		
"	1521	270	-3.1	-	90	"		Previous 6m dense Zm.
"	1523	280	-2.8	-	100	"		
"	1524	290	-3.1	-	100	"		270-290m dense, flowering Rm.
"	1525	300	-2.7	-	100	"	D3	
"	1540	310	-2.0	-	100	"		Dense, flowering Rm.
"	1541	320	-2.2	-	100	"		
"	1542	330	-2.1	-	90	"		
"	1543	340	-2.1	-	60	"		
"	1544	350	-2.0	-	50	"		
"	1545	360	-1.6	-	-	Coarse Sand		Sandbar evident, no vegetation.
"	1546	370	- .7	-	-	"		
"	1547	380	- .1	-	-	"		
"	1548	390	-1.9	-	5	Fine Sand		Rm patchy last 10m.
"	1550	400	-2.4	-	70	"	D4	
"	1600	410	-2.4	-	100	"		
"	1601	420	-1.4	-	5	"		Last 10m Rm less abundant.
"	1603	430	-2.4	-	20	"		
"	1604	440	-3.1	-	100	"		Very dense flowering Rm.
"	1605	450	-4.1	-	100	"		
"	1606	460	-4.4	20	80	"		
"	1607	470	-4.1	5	95	"		Zm occasional last 20m.

(continued)

TABLE D15 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-31-78	1608	480	-4.3	5	95	Fine Sand		
"	1610	490	-4.4	trace	100	"		
"	1612	500	-4.6	40	40	"	D5	Mixed Zm and Rm.
"	1620	510	-4.5	10	90	"		
"	1625	520	-3.6	-	70	"		
"	1628	530	-3.4	50	50	"		
"	1629	540	-2.8	-	90	"		No Zm last 10m.
"	1630	559	-1.8	-	-	Coarse Sand		
"	1631	550	-0.5	-	-			
"	1632	551	+ .8	-	-	Fine Sand		Rapid rise to sandbar.
"	1633	552	+1.6	-	-	"		
"	1634	553	+2.0	-	-	"		Transect ended.

---

[1] EDST

[2] Bearing of 290°mn

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4 dm

[4] Zm = *Zostera marina*
Rm = *Ruppia maritima*

APPENDIX D (continued)

TABLE D16: VAUCLUSE SHORES-TRANSECT E

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Sample #	Observations[4]
7-31-78	1710	0	+4.6	-	-	Coarse Sand		Transect begins at marsh edge.
"	1711	10	+ .8	-	100	"		Large patches Rm 1-3m diameter.
"	1712	20	+ .7	-	100	"		
"	1713	30	+ .1	-	50	"		
"	1714	40	+ .2	-	20	"		
"	1715	50	- .3	-	100	"		Dense Rm patches.
"	1716	60	- .5	-	100	"		
"	1717	70	- .5	-	-	"		Bare sand with scattered patches Rm 1m in diameter.
"	1718	80	-1.1	-	-	"		
"	1719	90	+1.1	-	-	"		
"	1720	100	- .1	-	-	"		Sparse Rm in vicinity.
"	1735	110	+ .1	-	-	"		Sparse Rm in vicinity.
"	1736	120	+ .4	-	-	"		
"	1737	130	+1.0	-	-	"		
"	1738	140	+ .7	-	-	"		
"	1740	150	+ .6	-	-	"		No Rm 140-160m.
"	1741	160	+ .2	-	-	"		
"	1742	179	+ .9	-	-	"		
"	1743	180	- .1	-	-	"		
"	1744	190	- .7	-	5	"		Scattered patches Rm.
"	1745	200	- .9	-	-	"		
"	1750	210	-1.1	-	60	"		
"	1751	220	-1.2	-	70	"		Sense and flowering Rm.

(continued)

APPENDIX D (continued)

TABLE D16 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Sample #	Observations[4]
7-31-78	1752	230	-1.7	-	100	Coarse Sand		
"	1753	240	-1.6	-	100	"		
"	1755	250	-1.9	-	100	"		
"	1756	260	-2.6	-	100	Fine Sand		Continued dense & flowering Rm.
"	1757	270	-2.1	-	100	"		
"	1758	280	-2.2	-	100	"		
"	1759	290	-2.4	-	100	"		
"	1800	300	-2.5	-	100	"	E6	Dense Rm no Zm evident.
"	1810	310	-3.4	-	100	"		
"	1812	320	-3.6	trace	100	"		Scattered trace amounts of Zm.
"	1814	330	-4.3	-	100	"		
"	1815	340	-4.2	trace	100	"		Scattered Zm throughout area.
"	1816	350	-3.2	-	100	"		Dense stands of Rm.
"	1818	360	-2.9	-	100	"		
"	1819	370	-2.9	-	-	"		Bare sand, scattered clumps Rm.
"	1820	380	- .7	-	-	"		
"	1821	390	+1.8	-	-	"		Rapid rise to sandbar, no vegetation evident.
"	1822	400	+1.4	-	-	"		

(continued)

APPENDIX D (continued)

TABLE D16 (continued)

Date	Time[1]	Distance[2] from shore line (m)	Elevation[3] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Sample #	Observations[4]
7-31-78	1823	410	+1.8	-	-	Fine Sand		No Rm last 20m, transect ended.

[1] EDST

[2] Bearing of 290° mn.

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4 dm.

[4] Zm = Zostera marina
Rm = Ruppia maritima

APPENDIX D (continued)

TABLE D17: VAUCLUSE SHORES-TRANSECT F

Date	Time[1]	Distance[2] from shore-line (m)	Elevation[3] (dm)	% Zm ($0.1m^2$)	% Rm ($0.1m^2$)	Bottom Type	Observations[4]
8-1-78	915	0	+7.5	-	-	Coarse Sand	Begin transect along sandy beach.
"	917	10	+2.9	-	-	"	
"	919	20	+1.8	-	10	"	Scattered Rm.
"	921	30	+1.3	-	50	"	
"	923	40	+ .9	-	100	"	
"	925	50	+ .6	-	100	"	Most areas of Rm mixed with dense epiphytic algae.
"	927	60	+ .6	-	100	"	
"	929	70	+ .2	-	100	"	
"	931	80	+ .2	-	40	"	
"	933	90	+ .3	-	95	"	Traces of Zp from 80-90m, approximately 5% bottom cover.
"	935	100	.0	-	100	"	
"	945	110	- .1	-	90	"	10% Zp.
"	947	120	- .9	-	100	"	Trace Zp.
"	949	130	-1.2	-	100	"	
"	950	140	-1.8	-	100	"	Very dense Rm, no Zp observed.
"	951	150	-1.8	-	100	"	
"	953	160	-2.1	-	100	Fine Sand	
"	955	170	-2.0	-	100	"	
"	956	180	-2.2	-	100	"	Continued dense Rm.
"	957	190	-1.4	-	100	"	
"	958	200	+1.7	-	-	Coarse Sand	Begin sandbar.
"	959	210	+5.0	-	-	"	

(continued)

APPENDIX D (continued)

TABLE D17 (continued)

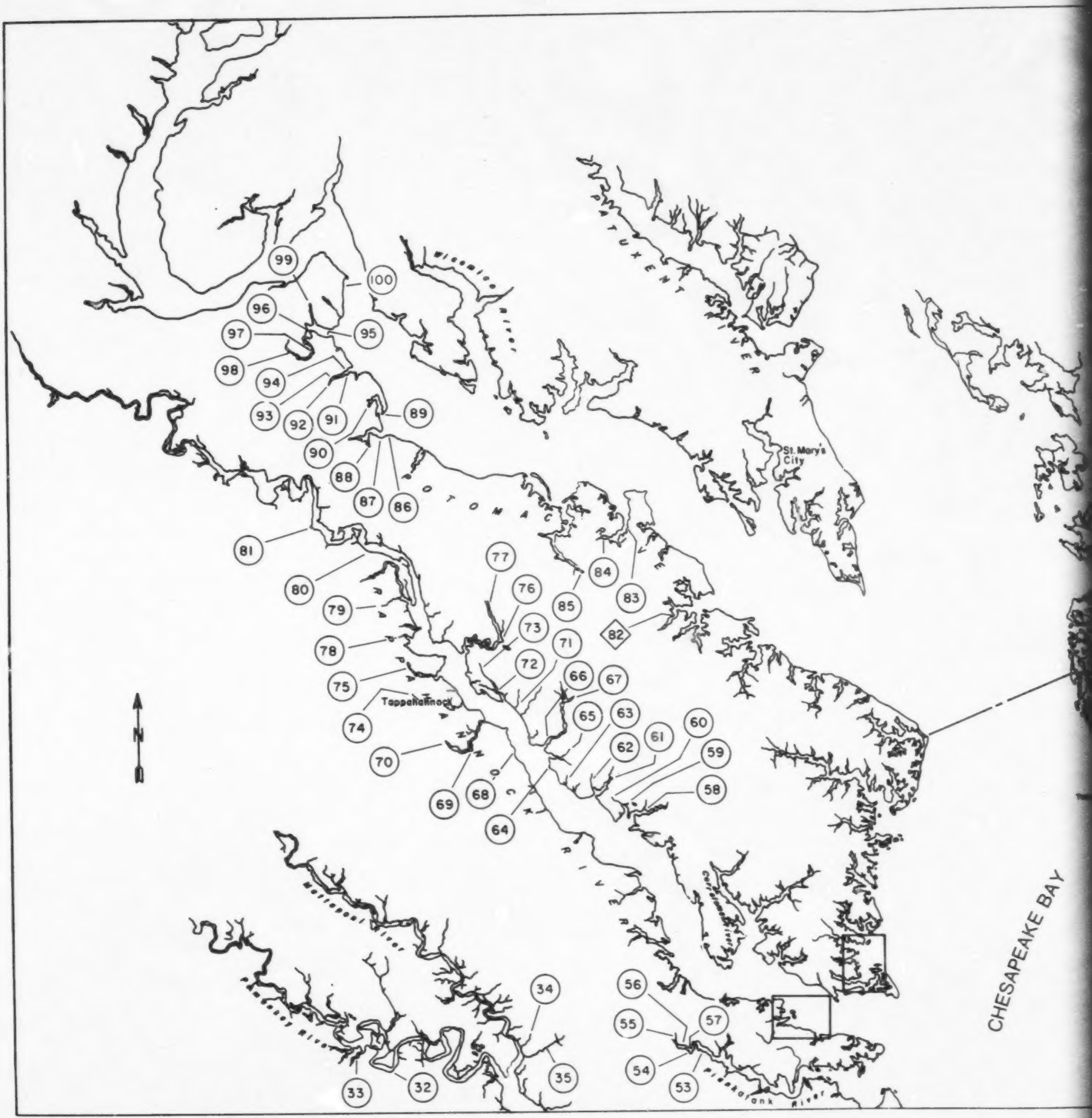
Date	Time[1]	Distance[2] from shore-line (m)	Elevation[3] (dm)	% Zm (0.1m^2)	% Rm (0.1m^2)	Bottom Type	Observations[4]
8-1-78	1000	220	+5.2	-	-	Coarse Sand	No vegetation in vicinity transect ended.

[1] EDST

[2] Bearing of 290°mn

[3] From calculated Mean Low Water (See Text)
N.O.S. mean tide range approximately 6.4 dm.

[4] Zp = Zannichellia palustris
Zm = Zostera marina
Rm = Ruppia maritima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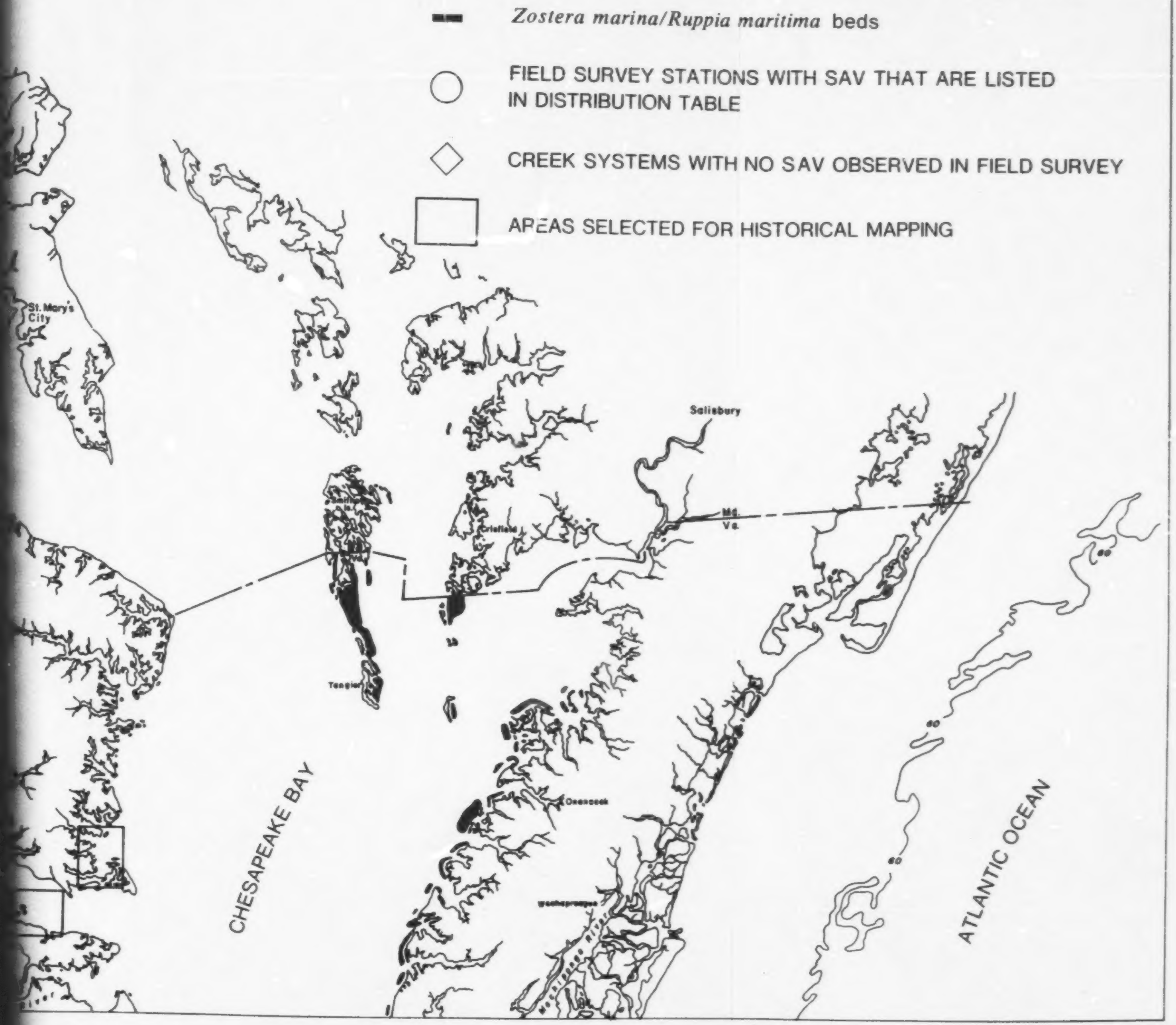
Wicomico River
PATUXENT RIVER
St. Mary's City
POTOMAC RIVER
RAPPAHANNOCK RIVER
Tappahannock
Corrotoman River
Mattaponi River
Pamunkey River
Piankatank River
CHESAPEAKE BAY
N

FIGURE 4. (continued) DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION IN VIRGINIA


▬ *Zostera marina/Ruppia maritima* beds
○ FIELD SURVEY STATIONS WITH SAV THAT ARE LISTED IN DISTRIBUTION TABLE
◇ CREEK SYSTEMS WITH NO SAV OBSERVED IN FIELD SURVEY
□ AREAS SELECTED FOR HISTORICAL MAPPING
St. Mary's City
Salisbury
Smith Is.
Crisfield
Md.
Va.
Tangier
Onancock
Wachapreague
Machipongo River
CHESAPEAKE BAY
ATLANTIC OCEAN
60
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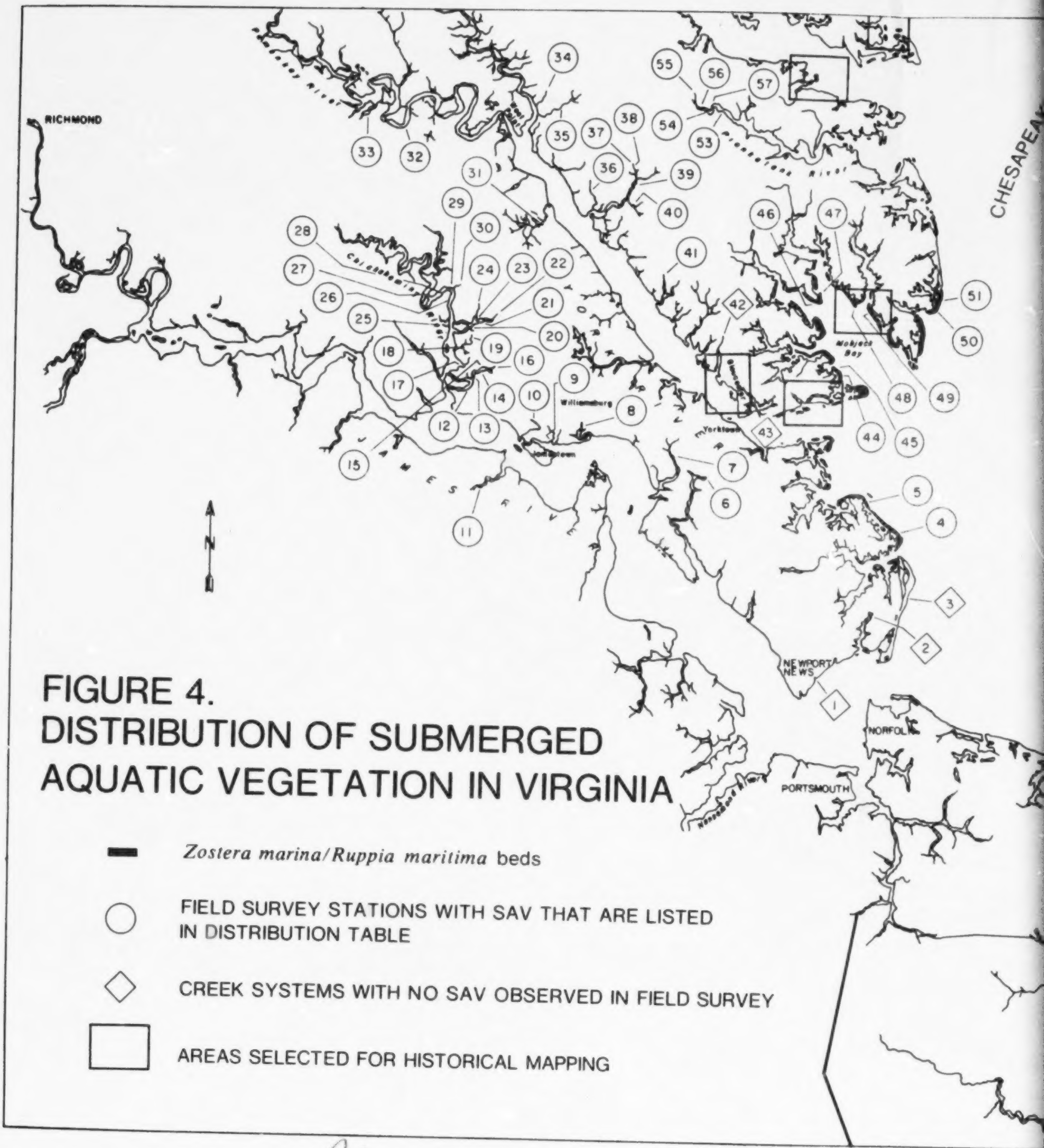
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Williamsburg
Jamestown
Yorktown
NEWPORT NEWS
NORFOLK
PORTSMOUTH
JAMES RIVER
Mobjack Bay
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FIGURE 4.
DISTRIBUTION OF SUBMERGED AQUATIC VEGETATION IN VIRGINIA

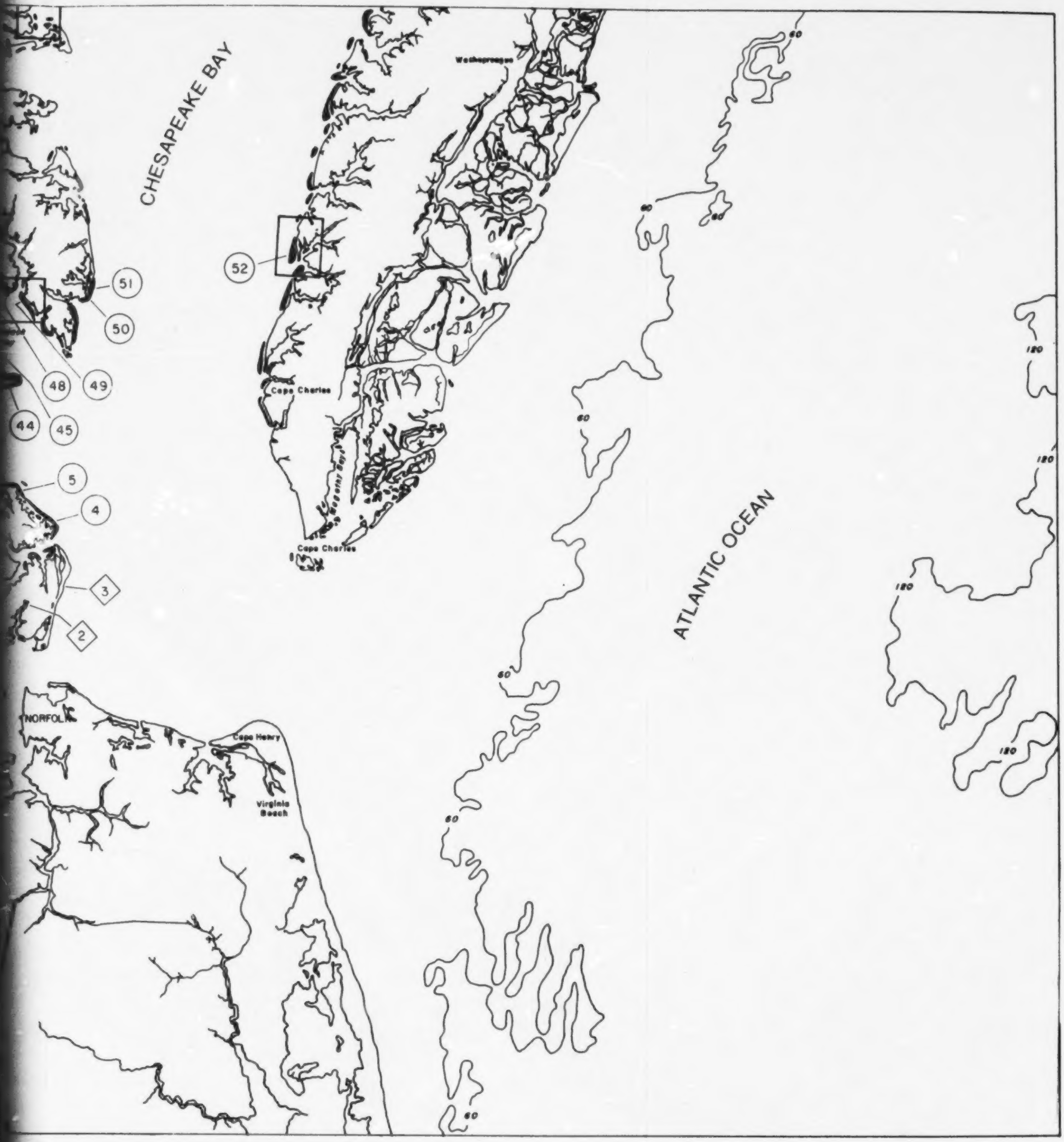
▬ *Zostera marina/Ruppia maritima* beds

○ FIELD SURVEY STATIONS WITH SAV THAT ARE LISTED IN DISTRIBUTION TABLE

◇ CREEK SYSTEMS WITH NO SAV OBSERVED IN FIELD SURVEY

☐ AREAS SELECTED FOR HISTORICAL MAPPING

A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Wachapreague
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Cape Charles
Magothy Bay
Cape Charles
NORFOLK
Cape Henry
Virginia Beach
ATLANTIC OCEAN
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